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ON FACTORS INFLUENCING FRUIT-SET AND STERILITY IN ARECANUT (*ARECA CATECHU* LINN.)

I. Studies on Pollen Grains

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Introduction

The arecanut (*Areca catechu* Linn., Palmæ) which is one of the most important of tropical fruits as a masticatory, is cultivated in the hot damp regions of Asia. In India arecanuts are grown extensively in Assam, Bengal, Bombay, Madras and the West Coast. Many different types of arecanut palms have been distinguished on the basis of the size of the fruits, majority being included in the single species, *A. catechu*. However, no comprehensive investigation on the different aspects of the life-history of this plant has been made except by Beccari (1919), Sands (1926), Milsum (1938) and Nambiar (1949) on the morphology and floral structure.

The plants are monœcious, male and female flowers occurring in the same spadix. A full grown spadix produces on an average of about 2,000–3,000 male flowers and 250–550 female flowers, the former constituting the panicle of the spadix and the latter occupying the basal region. It is generally observed that all the female flowers that are borne on the spadix do not yield fruits, a considerable majority of them falling off prematurely. The extent of sterility caused by such flower fall in the different plantations in Assam has been found to vary from 35–55 per cent. As the extent of sterility is high, the causes thereof are being investigated. The present work is based on observations made during two consecutive seasons in the different plantations.

One criterion used in classifying the palms is the size of the fruit and on this basis the different types are broadly separated into five groups: (i) Big oblong, (ii) Big round, (iii) Small oblong, (iv) Long and (v) Apex round fruits. There are, however, many variations in size in between the different types, intermediate types being not uncommonly found.

Material and Methods

In order to investigate this loss in fruit-set, the male flowers of the different types were examined to determine if sterility is associated with the nature and behaviour of the pollen grains. Maheshwari (1950) has emphasised the importance of pollen grains in relation to fruit-set in plants while Wodehouse (1935) and Erdtman (1952 *a*, *b*) have stressed the importance of morphological characters of pollen grains in taxonomy.

Inflorescences bearing the male flowers of the different types were collected from various localities at Gauhati. Fresh panicles were brought to the laboratory in the morning and pollen preparations were made in methyl-green glycerine jelly according to Wodehouse (1935). Preparations of two types from Jorhat, namely, 'apex round' and 'long', were made in the field itself and the slides were subsequently examined in the laboratory. The measurements of the grains were made with an ocular micrometer.

The causes of failure of germination of the pollen grains, in different types of arecanuts, resulting in lack of fertilization, have been studied in detail by determining the extent of germination of the pollen grains and the rate of elongation of the pollen tubes in different media. The effect of changes in the composition of the medium by using different types of carbohydrates such as sucrose, glucose, lævulose, maltose and starch was studied. The aqueous extracts of crushed stigmas of different types of arecanuts were also used. Germination counts were made in duplicate cultures at 28° C. by the hanging drop technique and in each case more than 100 counts were made to determine the extent of germination. The length of the pollen tubes was measured from time to time with an ocular micrometer.

Experimental

Fruit-set and sterility.—Estimates were made on the fruit-set and sterility in the different palms according to their types of fruits. The number of female flowers generally produced on the spadix and the number of fruits usually borne in the bunch were counted to determine the extent of fruit-set and sterility in each instance (Table I); figures for each type are based on the average of at least 20 bunches. The trees in the plantations are marked. The period intervening between flowers that have been observed and the fruits that have been formed in 5–7 months, was noted.

It will be seen from the above that fruit-set varies from 46–66 per cent. of the number of female flowers produced. Flower fall appeared to be related to the size of the fruits, the bigger sized fruits showing higher sterility than smaller types of fruits.

Morphology of pollen grains.—In all the types mature pollen grains show a similar morphology in having a reticulate exine (Fig. 1 *a*), a thin hyaline intine and a sharply defined oval furrow oriented parallel to the polar axis containing a small central germ pore-like structure

TABLE I

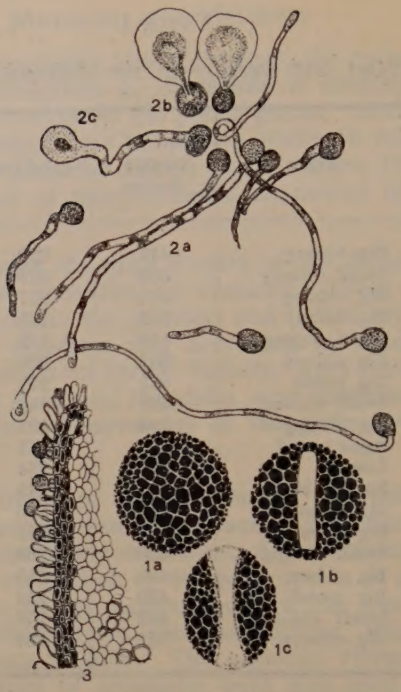
Extent of fruit-set and sterility in the different types of arecanuts

Locality	Type	No. of female flowers	No. of fruits	Extent of fruit-set %	Extent of sterility %
Charrapunji ..	Big oblong	446	220	49	51
	Small oblong	503	278	55	45
Dawki ..	Big oblong	460	237	52	48
	Big round	452	228	50	50
	Small oblong	419	252	60	40
Gauhati ..	Big oblong	502	260	52	48
	Big round	422	227	54	46
	Small oblong	488	289	59	41
Jorhat ..	Big oblong	394	192	49	51
	Apex round	469	282	60	40
	Long	420	254	60	40
	Small oblong	407	249	61	39
Nowgong ..	Big oblong	350	160	46	54
	Big round	428	221	52	48
	Small oblong	406	266	66	34
Palasbari ..	Big oblong	480	245	51	49
	Big round	469	234	50	50
	Small oblong	492	270	55	45
Sibsagar ..	Big oblong	522	287	55	45

(Fig. 1 *b*). The grains conform to the monocolpate type of Wodehouse (1935) or monosulcate of Erdtman (1952 *b*). The fertile grains were more or less spherical, but the sterile ones varied from ellipsoidal to sharply defined oval structures (Fig. 1 *c*). The sterile, crumbled or empty grains were of the same size as the fertile ones, but they could easily be distinguished by feeble staining reactions with methyl-green glycerine jelly. There were minor variations in size in the grains of the different types. The average range in size of the fertile and sterile grains was respectively 29·5–34·0 μ and 29·0–31·5 μ.

The anthers of the male flowers produce fertile pollen as well as sterile or imperfect grains. The extent of sterility is high, varying from 3·0–100·0 per cent. in the different types examined.

Pollination and flower fall.—In many plants premature flower fall is probably influenced to a great extent by the failure of pollination or by certain physiological factors or by both. Fruit-set is dependent on the normal development of the male and female reproductive units and the successful pollination of the stigmas affecting fertilization of the ovule. The high percentage of sterile grains in arecanuts indicates that one of the possible factors of sterility may be failure of pollination and subsequent failure of fertilization in some of the pollinated flowers. An attempt was, therefore, made to see if there is any defect in the normal course of events leading to fertilization and ultimate development of the fruit.



FIGS. 1–3. Fig. 1. Pollen grains. (*a*) Surface view of fertile grain showing reticulate exine. (*b*) Same showing furrow and 'germ pore'. (*c*) Sterile grain, × 350. Fig. 2. Germinating pollen grains. (*a*) Normal germination after 24 hours. (*b*) Pollen grains germinating into vesicles in high concentrations of medium. (*c*) Formation of vesicles at the tip of tubes, ×65. Fig. 3. Section through the mature stigma showing the elongated receptive cells and germinating pollen grains, ×15.

The male phase in arecanut palm begins immediately after the spadix frees itself from the spathe (Sands, 1926). The male flowers commence to open indiscriminately on the spadix; this phase continues for 2–4 weeks till all the male flowers are exhausted. At the close of the male phase, the green petals of the female flowers lengthen and change their colour to yellowish white. The petals slightly open at the tips and soon after, the receptive trifid stigmas are open to pollination. The female phase generally lasts for 4–5 days and during this period the flowers remain open all through, exposing their receptive stigmatic surfaces. The surface of the stigma is constituted of a special kind of thick-walled palisade-like cells which are closely packed in the young flowers but become elongated during maturity of the flower leaving interspaces in between them for the reception of the pollen grains (Fig. 3). Scrapings taken from the stigmas on consecutive days after opening of the female flowers showed that only a small percentage of them were pollinated.

The pollinated flowers which are successfully fertilized develop into mature fruits within 5–7 months. However, during the course

of 20–30 days after opening of the spadix, there is invariably falling off of certain proportions of female flowers, which are not so far being investigated. Table II shows the types of fallen flowers and their number in each collection from random samples.

TABLE II

Number of fallen flowers in each type

No. of collections	Total No. of flowers examined	Closed flowers	Slightly open flowers	Fully open flowers	Old flowers
1	184	36	13	118	17
2	85	4	16	61	4
3	191	13	19	152	7
4	128	..	10	117	1
5	89	..	..	80	9
6	66	..	2	61	3
7	144	5	28	102	9
8	63	3	9	42	9
9	58	2	9	45	2
10	111	3	3	92	13
11	88	3	5	71	9

It is apparent from the results that the majority of fallen flowers in the 11 samples observed were fully open with receptive stigmas. About 7 per cent. of them were old with the stigmas projecting considerably outside the perianth lobes. A small percentage of the fallen flowers were young and closed and abscised from the pedicels before there could be any chances for pollination. Some of the flowers though of a similar nature, were with their perianth lobes slightly open.

The flowers were further examined to find out whether they were pollinated, and if pollinated fertilization had occurred. The stigmas were examined by teasing and staining with methyl-green glycerine jelly and in some instances with lactic acid for clearing and then staining in acid fuchsin and light green. The results show that in the first and second groups pollination is not evident, whereas in the fully open flowers about 5 per cent. revealed the presence of pollen grains on the stigmas and in the old flowers only about 40 per cent. showed the presence of pollen grains on the stigmas. However, the pollen tubes were observed only in 15 per cent. of the pollinated open flowers and

12 per cent. of the pollinated old flowers. It is possible that only short tubes were produced. It is thus clear that a number of flowers remain unpollinated in nature and subsequently wither; this is further supported by the fact that the number of stigmatic surfaces with germinating pollen grains was somewhat low.

The pollinated flowers were sorted out and further examined to find out whether the ovules had been fertilised. The ovules, after carefully removing the outer fibrous integuments, were fixed in formalin-acetic-alcohol and embedded. Sections were cut 10–15 μ thick and stained in iron-hæmatoxylin, and safranin and light green. The sections of the female gametophytes showed that the egg apparatus was in a state of degeneration and there was no trace of the pollen tube. It is thus evident that fertilization had not occurred in the fallen flowers. It is possible that the failure of pollen grains to successfully germinate on the stigmas and produce sufficiently long tubes is one of the reasons for the failure of fertilization.

Germination of pollen grains.—The extent of germination and the average length of the pollen tubes during the first 24 hours of germination of the pollen grains of big oblong, big round and small oblong types are given in Table III; results are plotted in Figs. 4 and 5.

The pollen grains germinate readily in nutrient media, the percentage of germination depending on the medium employed, its concentration and the type of grain used. The highest rate of germination was observed in a big oblong type with sucrose—0·75–1·0 per cent., sucrose-gelatin—0·75–1·0 per cent., glucose—0·5–0·75 per cent., lævulose—0·1–1·0 per cent., maltose—0·25–0·5 per cent. and starch—0·5–1·0 per cent. The length of the pollen tubes in the different types varied from 15–600 μ according to the types of nutrient used. Pollen grains in high concentrations of media (2–10 per cent.) produced, however, big vesicles (Fig. 2 *b*). The percentage of germination in crushed aqueous stigmatic extracts showed no appreciable variation (60–80 per cent.) and the length of the pollen tubes did not in any concentration exceed 320 μ in 24 hours. The growth in length of the tubes was found to be related to the concentration of the medium up to a certain limit after which it decreased (Fig. 5). The increase in length of the tubes was observed up to 72 hours after which there was no further increase. In some cases growth of the tubes during or after the first 24 hours of sowing was followed by formation of vesicles at the tips (Fig. 2 *c*).

In another experiment the effect of varying the sowing period after the pollen grains have matured on the rate of germination of the pollen grains and elongation of the pollen tubes of different types of arecanuts was studied. Mature pollen was collected in watch-glasses and on slides from freshly opened flowers and stored in the laboratory at 88 per cent. R.H. and 28° C. Hanging drop cultures were made after

TABLE III

Extent of germination of the pollen grains and length of pollen tubes of the different types in 24 hours in different media

Type	Big oblong						Big round						Small oblong					
Media	S	SG	G	L	M	ST	S	SG	G	L	M	ST	S	SG	G	L	M	ST
Amount in gms. per 100 c.c. of the medium	Percentage of germination																	
0·1	6	20	22	25	20	20	5	25	20	50	25	3	15	15	5	10	25	12
0·25	13	30	75	..	60	35	7	35	23	20	32	8	22	20	40	15	28	18
0·5	30	45	92	..	20	82	15	45	35	18	40	23	28	22	42	25	28	36
0·75	40	48	72	..	15	82	17	48	15	15	40	28	48	50	55	25	..	39
1·0	85	85	50	..	8	72	12	30	12	3	20	26	42	22	30	50	..	29
2·0	35	80	30	..	5	50	5	12	2	3	20	20	20	20	30	25	..	9
5·0	25	50	20	..	5	25	5	1	2	3	18	8	12	20	15	25	..	3
10·0	22	25	18	..	5	25	5	..	..	..	10	2	5	20	5	20	..	3
	Length of pollen tubes in μ																	
0·1	51	35	150	120	60†	150†	20	60†	20	20	25	15	100	120	20	60†	100	90
0·25	60	42	400	..	75	172	25	60	300	60	200	23	150	300	20	120†	60	120†
0·5	210	100	600	..	90	600	25	90	600	60	350	250	200	500	200	400†	60	500†
0·75	210	180	120	..	120*	500†	36	90	100	120	500	390	500	355	200	500†	..	520†
1·0	210	500†	120	..	25*	500	36	60	100	15*	120	402†	450†	350	100	500†	..	530†
2·0	60	450†	50	..	25*	40	32†	30	15	15*	120	120*	200†	36*	100	60*	..	30*
5·0	50*	200	30	..	15*	35*	15*	30*	15	15*	50*	60*	50*	30*	100	60*	..	30*
10·0	40*	45*	20	..	15*	35*	15*	..	..	..	40*	15*	50*	30*	60	60*	..	15*

* Grains germinating into big vesicles.

† Tip of pollen tubes enlarging into vesicles during or after 24 hours of germination.

S = Sucrose; SG = Sucrose + 1% Gelatin; G = Glucose; L = Lævulose; M = Maltose; ST = Starch.

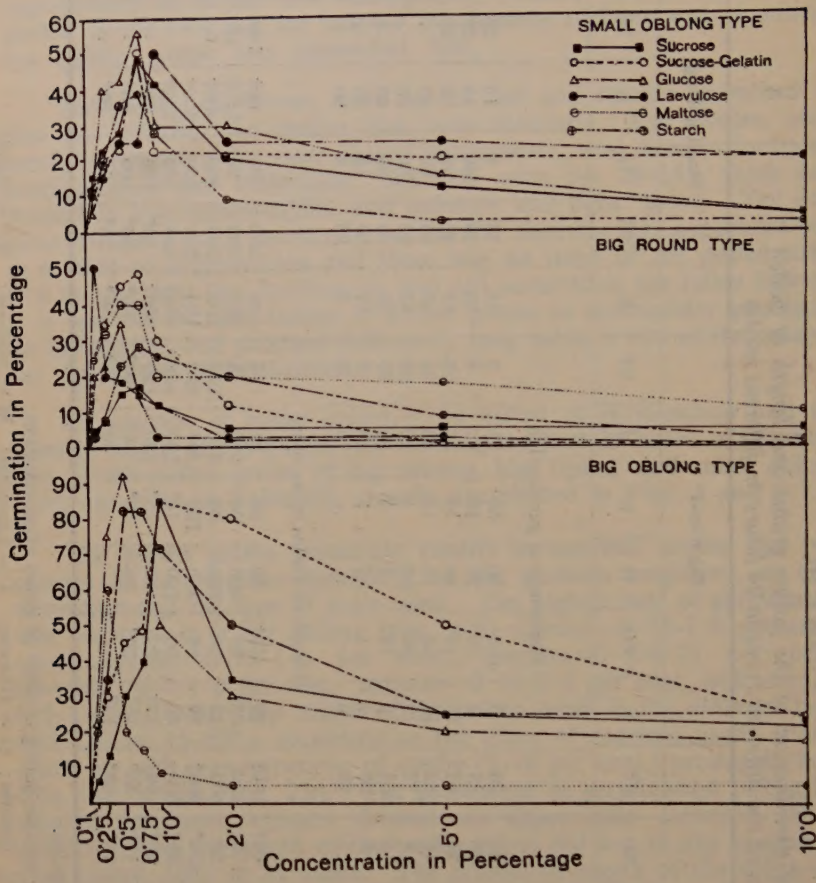


FIG. 4. Percentage of germination of pollen grains in different concentrations of media.

every one hour; the percentage of germination and the growth in length of the tubes were noted after 24 hours (Table IV and Fig. 6).

It is seen that the viability of the pollen grains after maturity extended up to 9 hours. The sowing of grains during only the first few hours showed the best results, optimum being at 2–3 hours.

The effect of temperature on the extent of germination of the pollen grains and the rate of growth of pollen tubes was also studied in

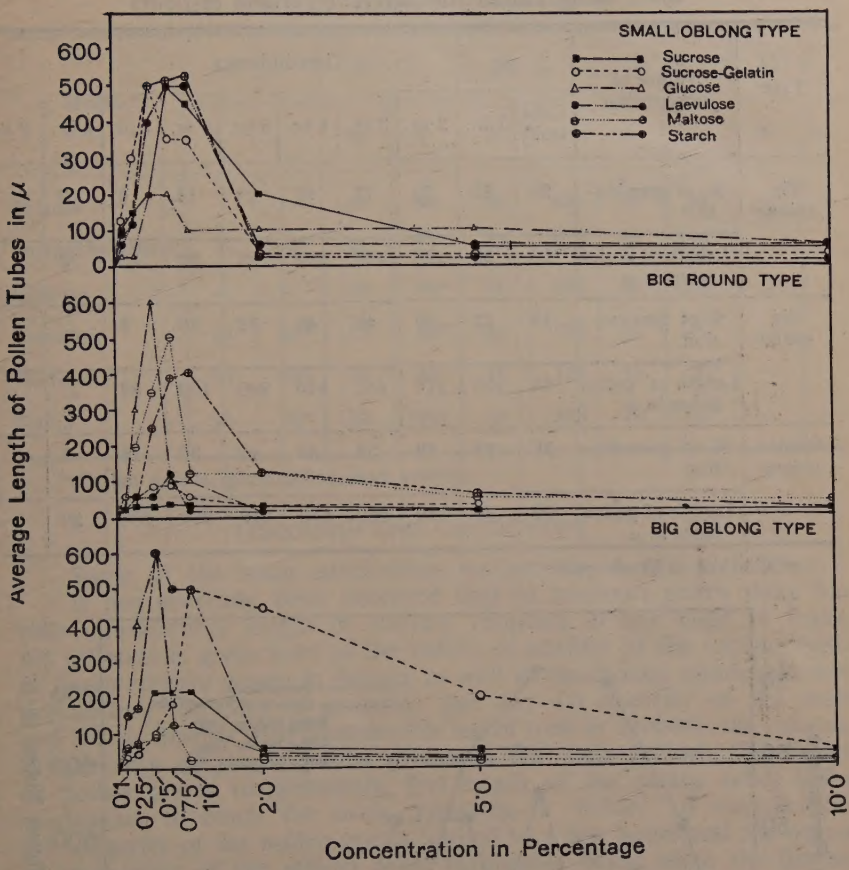


FIG. 5. Rate of growth of pollen tubes in different concentrations of media.

1·0 per cent. sucrose, 1·0 per cent. sucrose-gelatin, 0·5 per cent. glucose, 0·1 per cent. lævulose, 0·25 per cent. maltose and 0·5 per cent. starch at 15° C., 20° C., 28° C., 30° C. and 35° C. The extent of germination and the rate of growth of the pollen tubes were measured after 24 hours and are shown in Table V.

The optimum temperature was found to be at 28° C. whereas temperatures of 15° C., 20° C., 30° C. and 35° C. were inhibitory to successful germination of pollen grains.

TABLE IV

Extent of germination and length of pollen tubes of grains sown after being stored for different periods in hours

Type	Nature of observation	Time in hours									
		Control*	1 hr.	2 hr.	3 hr.	4 hr.	5 hr.	6 hr.	7 hr.	8 hr.	9 hr.
Big oblong	% of germination	20	50	70	72	60	28	14	6	3	..
	Length of pollen tubes in μ	20	20	220	550	230	20	20	20	10	..
Big round	% of germination	10	22	30	40	40	32	10	8	..	..
	Length of pollen tubes in μ	25	100	210	420	420	200	100	82	..	..
Small oblong	% of germination	21	23	29	38	43	42	32	18	6	..
	Length of pollen tubes in μ	60	66	120	220	510	510	266	200	20	..

* Control = Fresh pollen.

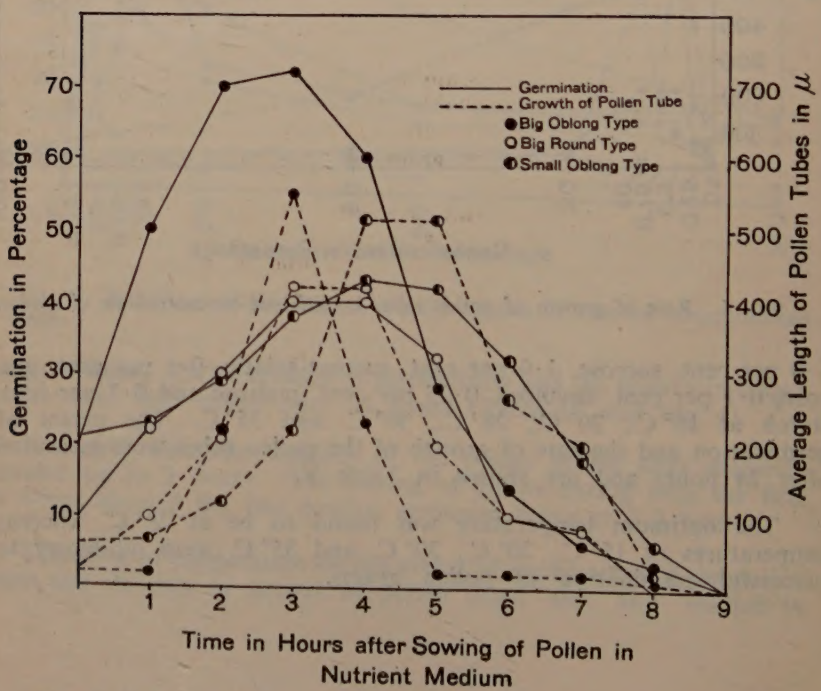


FIG. 6. Effect of storage of pollen grains on the extent of germination and average length of pollen tubes.

TABLE V

Percentage of germination and length of pollen tubes after 24 hours at different temperatures

Media	15° C.		20° C.		28° C.		30° C.		35° C.	
	%	μ	%	μ	%	μ	%	μ	%	μ
Sucrose ..	..	..	30	60	60	421	30	60	..	..
Sucrose-gelatin ..	5	15*	33	75	60	392	36	130	..	..
Glucose ..	..	..	10	30*	75	576	40	220	..	..
Lævulose ..	10	20*	15	40*	20	223	18	100	..	..
Maltose ..	10	20*	10	60	16	138	10	30*	..	..
Starch ..	20	20*	25	100*	65	568	20	60*	..	..

* Pollen grains germinating into vesicles.

DISCUSSION AND CONCLUSIONS

Some of the main conclusions reached above are as follows:—

It has generally been observed that in arecanut palms there has been considerable extent of sterility resulting in low yield of fruits. An estimate is given here of the extent of sterility of the various types of *Areca catechu* grown in Assam, as well as the factors which influence pollination. Sterility is probably due to: (i) maturity of the male and female flowers with considerable lag of time in between the phases, (ii) presence of sterile pollen grains in the male flowers, (iii) failure of pollen grains to germinate, (iv) length of the pollen tubes being inadequate to reach the ovule resulting in failure of fertilization, (v) longevity of the pollen grains limited to a few hours and the degree of receptivity of the stigma most favourable being when the flowers are slightly open, and (vi) effect of temperature on the germination of pollen grains.

It may be noted that the time lag in the maturity of the male and female flowers is a natural adaptation to prevent self-pollination. Sands (1926), however, indicates the possibility of pollination from the male flowers of the spadix opening successively in the same palm.

The percentage of sterile pollen grains in the male flowers in different types of arecanuts is considerably high. Such a high sterility is generally characteristic of hybrids and the question whether the different types of arecanuts are really morphologically different or merely unstable hybrids requires further investigation.

In the formation of fruits the lodging of the pollen grains on the stigma under natural conditions and its subsequent germination leading

to fertilization of the ovule are important factors. It has been observed that not more than 75 per cent. of the female flowers actually receive pollen on their stigmatic surfaces. Naik and Rao (1943) and Mukherjee (1951) working on the blossom biology of mangoes have made similar observations. The main problem, however, is not in regard to the lodging of the pollen grains on the stigmas and their capacity to germinate but in the active growth of the pollen tubes inside the sytlar canal leading to fertilization of the ovule. The failure of pollen tubes to fertilize the ovules may be due to: (i) maximum length of the pollen tube being inadequate to reach the ovule, (ii) medium of the stylar canal failing to promote optimum growth of the pollen tubes, and (iii) bursting of the pollen tubes inside the stylar canal or formation of vesicles at the tip of the tubes. In this connection it is worthwhile to note that the length of the style varied from 0·8–1·3 cm. in the different types and the maximum length attained by the pollen tubes in cultures under optimum conditions is rather incompatible with the length of the style. Furthermore, evidence has already been given of the frequent occurrence of vesicles at the tip of pollen tubes in cultures. However, the observations based on experiments *in vitro* are necessarily different from conditions *in vivo*, but it has not been possible to determine the nature of growth of the pollen tube in the stylar canal. The ephemeral nature of the pollen grains and the degree of receptivity of the stigmas are also factors that determine successful pollination and fertilization. In the case of arecanuts, pollen grains lose their viability within 8–9 hours after dehiscence; stigmas in mature flowers also exhibit rapid loss of receptivity. It has been further found that certain nutrient solutions favour production of long tubes and successful germination of the pollen grains. The effect of nutrients may serve as a basis for further studies on specific stimuli or auxins that may be responsible for quicker initiation of germination and active growth of the pollen tubes than hitherto obtained, because there is evidence that even the stylar extracts do not increase sufficiently the extent of germination of the pollen grains and length of the pollen tubes.

It is evident, therefore, that failure of pollination and fertilization primarily accounts for a considerable proportion of the fallen flowers in arecanut palms. Approximately 15 per cent. of the flowers wither and abscise before there could be any chances of pollination. The factors which influence the abscission of the young flowers are still, however, imperfectly understood.

Summary

1. The fruit-set and sterility in different types of arecanuts of Assam have been studied; only 46–66 per cent. of the female flowers set fruits and mature.

2. Pollen grains of different types of arecanuts are morphologically similar, but the anthers exhibit varying degrees of sterility.

3. The fall of female flowers during premature stages is due to failure in pollination and fertilization.

4. The extent of germination of the pollen grains and the rate of growth of the pollen tubes have been studied under different conditions.

ACKNOWLEDGEMENT

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ADDITIONS TO OUR KNOWLEDGE OF RUSTS OF HYDERABAD—II

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Introduction

The material for the paper was mostly collected from Narsapur Forest Reserve, situated at a distance of 36 miles from Hyderabad City. This part of the country is typical of the Telangana side. Much of the open country contains the thorn forest or scrub jungle, common mostly on laterite and on rocky soil, but nearing Narsapur, one sees luxuriant tree vegetation. The forest consists of mixed deciduous species, considerably thicker and containing a good deal of *Tectona grandis* Linn., *Buchanania latifolia* Roxb., *Dalbergia latifolia* Roxb., and many species of *Albizzia.*

Aecidium barleriæ sp. nov.

Rust spots circular, yellowish; pycnia not observed; æcia, hypophyllous, in groups, bright yellow, subepidermal, peridiate, measuring 150–240 × 132–198 μ; peridial cells polygonal, hyaline, thick-walled, verrucose, 18–28 × 14–22 μ; æciospores catenulate, subglobose or polygonal, with orange contents, 16–24 × 8–12 μ.

Habitat.—On living leaves of *Barleria cuspidata* Heyne (Acanthaceæ), private gardens, Hyderabad-Dn., 22–8–1955, Coll. Miss Videhi Iyengar, O.U.B. 'Hy' No. 19.

Maculæ circulares, luteolæ; pycnia haud observata; æcia hypophylla, aggregate, lucide lutea, subepidermalia, peridiata, magnit. 150–240 × 132–198 μ; cellulæ peridiales polygonales, hyalinæ, crassis parietibus præditæ, verrucosæ, 18–28 × 14–22 μ; æciosporæ catenulatæ, subglobusæ vel polygonales, contentis aurantiacis, 16–24 × 8–12 μ.

Typus lectus in foliis viventibus *Barleriæ cuspidatæ* Heyne e familia Acanthacearum, in hortis privatis, in loco Hyderabad-Dn. die 22 mensis augusti 1955 a Videhi Iyengar, et positus in O.U.B. 'Hy' sub-numero 19.

This rust does not seem to have been reported before on this host. Hence it is described as a new species.

Aecidium ocimi P. Henn.

Saccardo, P. A., *Syll. Fung.*, **11**: 218, 1911.

Only æcia were present.

Habitat.—On living leaves of *Ocimum canum* (Labiatæ), University Campus, 25–8–1955, Leg. P.R. O.U.B. 'Hy' No. 20.

Aecidium ocimi P. Henn. has not so far been reported from India. An *Aecidium* collected by McRae from Koilpatti on *Ocimum canum* was identified by Sydow (1914) as *A. ocimi* P. Henn. and listed as such by Butler and Bisby (1930). However, in 1917 Sydow made the same specimen the basis of his new species *Aecidium leiocarpum* Syd. *A. ocim* P. Henn. is therefore, being recorded from this country for the first time here.

Melampsora euphorbiæ-gerardianæ W. Mueller

Saccardo, P. A., *Syll. Fung.*, **23**: 232, 1925; Butler, E. J. and Bisby, G. R., *Sci. Monogr. Coun. agric. Res. India*, No. **1**: 60, 1930.

Only telia were present.

Habitat.—On the living leaves of *Euphorbia* sp. (Euphorbiaceæ), University Campus, 12–5–1954, Leg. M.A.S. and P.R. O.U.B. 'Hy' 21.

Hemileia vastatrix Berk. and Br.

Butler, E. J. and Bisby, G. R., *Sci. Monogr. Coun. agric. Res. India*, No. **1**: 59, 1930.

Both uredia and telia were present.

Habitat.—On the living leaves of *Coffea arabica* L. (Rubiaceæ), Botanic Gardens, Osmania University, Leg. P.R. and M.A.S. O.U.B. 'Hy' No. 22.

Puccinia polygoni-amphibii Pers.

Saccardo, P. A., *Syll. Fung.*, **17**: 394, 1905.; Butler, E. J. and Bisby, G. R., *Sci. Monogr. Coun. agric. Res. India*, No. **1**: 71, 1930.

Only telia were present.

Habitat.—On living leaves of *Polygonum* sp. (Polygonaceæ), Mannanoor Forest, 22–12–1954, Leg. P.R. O.U.B. 'Hy' No. 23.

Puccinia shiraiana Syd.

Saccardo, P. A., *Syll. Fung.*, **16**: 300, 1902.; Butler, E. J. and Bisby, G. R., *Sci. Monogr. Coun. agric. Res. India*,. No. **1** 76, 1930; Thirumalachar, M. J., in *Mycologia*, **39**: 231–48, 1947.

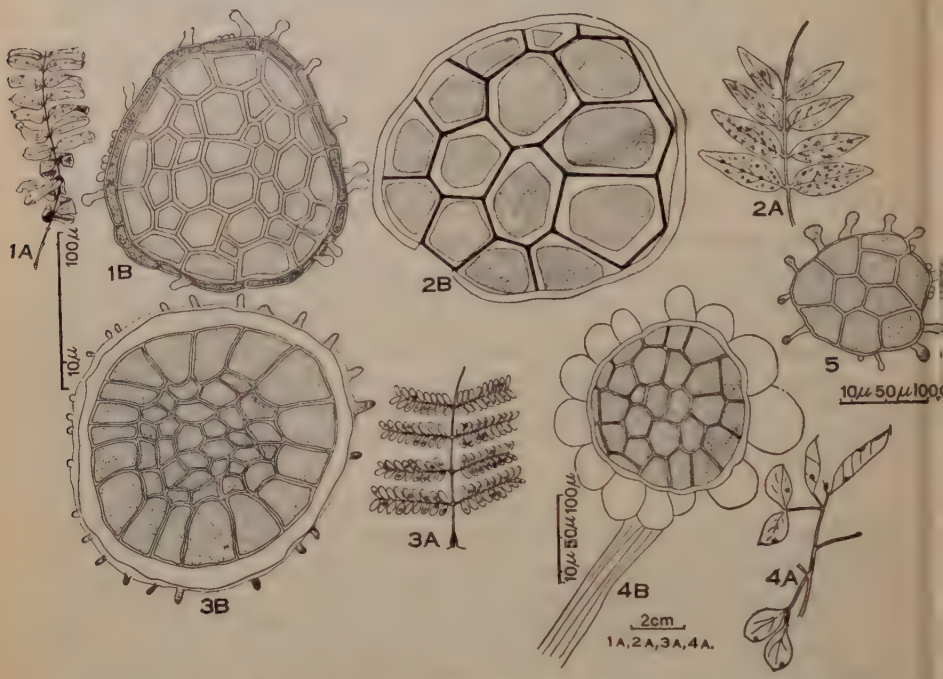
Aecia and telia were present.

Habitat.—On living leaves of *Justicia* sp. (Acanthaceæ), Narsapur Forest, 5–12–1954, Leg. P.R. O.U.B. 'Hy' No. 24.

Ravenelia sayeedii sp. nov.

Pycnia and æcia unknown; Telia mostly hypophyllous, black, subepidermal, erumpent, scattered, infection spots up to 0·6 mm. in diameter; teliospore heads almost spherical, chestnut brown, 50–90 μ in diameter, with 3–4 spores in cross-section; teliospores one-celled, measure 24–40 $\times$ 16–28 μ; cysts absent; pedicel hyaline, compound, decidious, very short.

Habitat.—On living leaves of *Sophora glauca* Lesch., (Papilionaceæ), Mannanoor Forest, 28–12–1953, Leg. P.R. O.U.B. 'Hy' No. 25.



FIGS. 1–5. Fig. 1. (*a*) Leaf of *Albizzia odoratissima* showing the telia of *Ravenelia japonica*, (*b*) Telial heads of *R. japonica*. Fig. 2. (*a*) A part of the leaf of *Sophora glauca* showing the telia of *Ravenelia sayeedii*, (*b*) Telial head of *R. sayeedii*. Fig. 3. (*a*) A part of the leaf of *Albizzia amara* showing the telia of *Ravenelia albizziæ-amaræ*, (*b*) Telial head of *R. albizziæ-amaræ*. Fig. 4. (*a*) A part of the twig of *Cassia absus* showing the telia of *Ravenelia berkeleyi*, (*b*) Telial head of *R. berkeleyi*. Fig. 5. Telial head of *Ravenelia ornata*.

Pycnia atque æcia ignota. Telia ut plurimum hypophylla, nigra, subepidermalia, dispersa; infectionis maculæ usque ad 0·6 mm. diam. Teliosporarum capitula fere sphærica, castaneobrunnea, 50–90 μ diam., ornata 3–4 maculis in sectione transversali; teliosporæ unicellulatæ, magnit. 24–40 × 16–28 μ; cystis absentibus, pediculo hyalino, composito, deciduo, brevissimo.

Typus lectus in foliis viventibus *Sophoræ glaucæ* Lesch., e familia Papilionacearum, in silva Mannanoor, die 28 mensis decembris anni 1953, a P.R. et positus in O.U.B. 'Hy' sub-nemero 25.

There seems to be no record of this rust occurring on the present host. Hence it has been described as a new species and named after Prof. M. Sayeeduddin, well-known taxonomist in Angiosperms.

Ravenelia albizziæ-amaræ Baccarini.

Saccardo, P. A., *Syll. Fung.*, **23**: 707, 1925; Mundkur, B. B. and Thirumalachar, M. J., Revisions of and additions to Indian Fungi, I, *Mycol. Pap.*, **16**: 27, 1946.

Only telia were present.

Habitat.—On living leaves and fruits of *Albizzia amara* Boiv. (Mimosaceæ), Narsapur Forest (Hanumanthapuram), 5–12–1954, Leg. P.R. O.U.B. 'Hy' No. 26.

Ravenelia berkeleyi Mundkur and Thirumalachar.

Mundkur, B. B. and Thirumalachar, M. J., in Revisions of and additions to Indian Fungi, I, *Mycol. Pap.*, **16**: 27, 1946.

Both uredia and telia were present.

Habitat.—On living leaves, stems and fruits of *Cassia absus* L., (Cæsalpinaceæ), Narsapur Forest, 5–12–1954, Leg. P.R. O.U.B., 'Hy' No. 27.

Ravenelia hobsoni Cke.

Butler, E. J. and Bisby, G. R., *Sci. Monogr. Coun. agric. Res. India*, No. **1**: 76, 1930.

Only telia were present.

Habitat.—On living leaves of *Pongamia glabra* Vent. (Papilionaceæ), on the banks of the canal, Lingampalli, Hyderabad-Deccan, 10–12–1953, Leg. M.A.S. and P.R. O.U.B. 'Hy' No. 28.

Ravenelia japonica Diet and Syd.

Saccardo, P. A., *Syll. Fung.*, **16**: 336, 1902; Mundkur, B. B., in *Sci. Monogr. Coun. agric. Res. India*, No. **12**: 23, 1938.

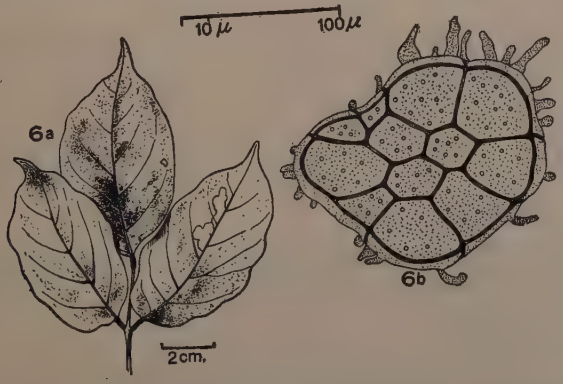


FIG. 6. (*a*) Leaf of *Pongamia glabra* showing the telia of *Ravenelia hobsoni*, (*b*) Telial head of *Ravenelia hobsoni*.

Both uredia and telia were present.

Habitat.—On living leaves and fruits of *Albizzia odoratissima* Wall. (Mimosaceæ), Narsapur Forest, 22–6–1955, Leg. P.R. and M.A.S. O.U.B. 'Hy' No. 29.

Ravenelia emblicæ Syd.

Butler, E. J. and Bisby, G. R., *Sci. Monogr. Coun. agric. Res. India*, No. **1**: 76, 1930.

Only telia were present.

Habitat.—On living leaves and fruits of *Phyllanthus emblica* Linn. (Euphorbiaceæ), Botanic Gardens, Osmania University, 20–8–1954, Leg. P.R. and M.A.S. O.U.B. 'Hy' No. 30.

The rust has been hitherto reported to occur on the leaves only.

Ravenelia mitis Syd.

Butler, E. J. and Bisby, G. R., *Sci. Monogr. Coun. agric. Res. India*, No. **1**: 77, 1930.

Only telia were present.

Habitat.—On living leaves of *Tephrosia purpurea* Pers. (Papilionaceæ), University Campus, 20–8–1954, Leg. P.R. O.U.B. 'Hy' No. 31.

Ravenelia ornata Syd.

Saccardo, P. A., *Syll. Fung.*, **21**: 738, 1912.; Butler, E. J. and Bisby, G. R., *Sci. Monogr. Coun. agric. Res. India*, No. **1**: 77, 1930.

Both uredia and telia were present.

Habitat.—On living leaves of *Abrus precatorius* Linn. (Papilionaceæ), Botanic Gardens, Osmania University, 5–6–1954, Leg. M.A.S. O.U.B. 'Hy' No. 32.

This rust has been reported previously on *Abrus pulchellus* Wall., The present host seems to be new.

Uromyces mucunæ Rabenh.

Butler, E. J., and Bisby, G. R., *Sci. Monogr. Coun. agric. Res. India*, No. **1**: 83, 1930.

Only telia were present.

Habitat.—On living leaves of *Mucuna* sp. (Papilionaceæ), Narsapur Forest, 26–12–1954, Leg. P.R. and M.A.S. O.U.B. 'Hy' No. 33.

Uromyces hobsoni Vize.

Butler, E. J. and Bisby, G. R., *Sci. Monogr. Coun. agric. Res. India*, No. **1**: 82, 1930; Thirumalachar, M. J., *Phytopathology*, **29**: 785, 1939.

Pycnia, æcia and telia were present.

Habitat.—On living leaves, petioles, stem and flowers of *Jasminum grandiflorum* L. (Oleaceæ), Narsapur Forest and private gardens, Hyderabad-Deccan, 22–8–1955, Leg. M.A.S. and P.R. O.U.B. 'Hy' No. 34.

Summary

The present paper records 16 species of rusts, *viz.*, *Aecidium barleriæ*, *Aecidium ocimi*, *Melampsora euphorbiæ-gerardianæ*, *Hemileia vastatrix*, *Puccinia polygoni-amphibii*, *Puccinia shiraiana*, *Ravenelia sayeedii*, *R. albizziæ-amaræ*, *R. berkeleyi*, *R. hobsoni*, *R. japonica*, *R. emblicæ*, *R. mitis*, *R. ornata*, *Uromyces mucunæ* and *U. hobsoni*, occurring on various angiosperms collected from the vicinity of Hyderabad and Narsapur Forest. Out of these the rusts, *Ravenelia sayeedii* on *Sophora glauca* and *Aecidium barleriæ* on *Barleria cuspidata*, are new species. *Abrus precatorius* is reported as an additional host for *Ravenelia ornata*.

Acknowledgment

The authors wish to express their indebtedness to Prof. M. Sayeeduddin for his keen interest and encouragement. Thanks are due to Rev. Dr. H. Santapau, for the Latin diagnosis of the new species and to the Officers of the Royal Botanic Gardens, Sibpur, for identifying some of the host plants and also to Prof. T. S. Sadasivan and Dr. C. V. Subramanian of Madras, for their helpful suggestions.

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Sydow, H. & P. 1917. Novæ fungorum species—XV. *Ibid.*, **15**: 143–48.

OBSERVATIONS ON INTER-RACIAL RICE HYBRIDS

The *japonica-indica* Rice Hybridisation

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(Received for publication on October 3, 1955)

Introduction

The genus *Oryza sativa* Linn. is divided into two main races, *viz.*, (1) forma *japonica* and (2) forma *indica*. The *japonicas* are characterised by short stature, stiff straw, long panicle, non-lodging habit and possess what is known as 'the response to high fertility'. The *indica* forms are tall and lodge even under normal manurial conditions and are poor responsers to high fertilization. In order to combine the useful genes of these two forms, the *japonica-indica* rice hybridisation programme was launched by the F.A.O. at the Central Rice Research Institute, Cuttack, India, and the F_1 hybrid seeds were sent to participating countries and Indian States for study and selection from the first segregating generation onwards. It is generally believed that a large number of gene mutations and gene rearrangements within the chromosomes have accumulated in the *japonicas*, on account of their cultivation in entirely different agro-climatic conditions (Jones and Longley, 1941) which largely accounts for the sterility in the hybrids. As a detailed study of the F_2 progenies for various characters offers the earliest opportunity for estimating the value of crosses, an attempt is made here to present the results of observations on the *japonica-indica* rice hybrids.

Materials and Methods

The following F_1 seeds were received from the Central Rice Research Institute, during the year 1953–54. (1) Rikuu 132×141 B.K., (2) Norin 18×36 B.K. and (3) Norin 18×141 B.K. Seedings raised from well manured beds were transplanted singly when they were 20 days old, with a spacing of one foot between plants and between rows, at a fertility level of 40 lb. N and 20 lb. P_2O_5 per acre, applied in the form of ammonium sulphate and single superphosphate, respectively, after an initial green manuring of 1,000 lb. per acre. The parent plants, *japonica* and *indica* types, were also grown side by side, with the hybrid population and a comparison was made between them for their performance. Observations on plant height, flowering dates, number of productive tillers, paddy colour and presence of awn, were made on individual hybrid progenies. Hybrid plants selected for F_3 generation were studied for adaptability to heavy manuring under a fertility level of 80 lb. N and 40 lb. P_2O_5 per acre.

OBSERVATIONS

(*a*) *General* (*Qualitative*)

The first segregation *japonica-indica* rice hybrids segregate for various characters. In some of the progenies was noticed varying intensities of vegetative colouration like light and dark green. None of the progenies showed any tendency for lodging, though some of the *indica* parents, raised side by side, lodged at full maturity. In a similar study on *japonica-indica* crosses, Rajagopalan (1955) observed segregation for vegetative colouration as well as for lodging.

(*b*) *Quantitative*

The various quantitative characters studied in the population are presented in Tables I, II and III.

TABLE I

Showing the characters of the parents in the japonica-indica *rice crosses*

No.	Plant characters	japonicas	indicas
1	Height in cm. ..	68—75	120—130
2	Flowering duration (from sowing to ear-emergence) in days ..	75—80 (late August flowering)	120—25 (late Oct. flowering)
3	Number of productive tillers	15—20	8—10
4	Paddy (in husk) colour ..	Straw	Straw (36 BK) Brown (141 BK)
5	Presence of awn ..	Awnless	Tipped (36 BK) Awnless (141 BK)
6	Rice grain (Kernel) colour ..	White	White

(i) *Plant height.*—Height measurements show that *japonica* parents range from 68–75 cm. while *indica* parents measure 120–130 cm. (Table I). The F_2 progenies of these parents show a wide range in height within the parental limits. Table II shows that in all the crosses studied, there is a preponderance of intermediate types except in the case of Rikuu 132×141 B.K. The table also shows that *indica* types are recovered in greater percentage than *japonica* types, in all the crosses.

(ii) *Flowering duration.*—*Japonicas* flower by about late August and their flowering duration is about 75–80 days (Table I), while *indicas* take about 120–125 days to flower from the date of sowing. Hybrid population of these two forms show that the flowering duration may be inherited in a simple Mendelian ratio (Norin 18×36 B.K. and Norin 18×141 B.K.) or the inheritance may be multi-factorial transgressing either sides of the parental limits (Rikuu 132×141 B.K.). Table II shows that, in the inheritance of flowering duration in the latter cross (Rikuu 132×141 B.K.), there is a tendency for a shift towards

TABLE II

Showing the segregation of characters in the F_2 progenies japonica-indica *rice hybrids*

No.	Characters	RIKUU 132 × 141 B.K. No. of progenies conforming to					NORIN 18 × 36 B.K. No. of progenies conforming to			NORIN 18 × 141 B.K. No. of progenies conforming to		
			japonica type	Intermediate	*indica* type		*japonica* type	Intermediate	*indica* type	*japonica* type	Intermediate	*indica* type
1	Height ..		654 (25·72)	911 (35·82)	978 (38·49)		298 (26·68)	437 (39·00)	384 (34·33)	49 (19·84)	114 (46·15)	84 (34·00)
2	Flowering duration	76 (2·99) (Earlier than Rikuu)	348 (13·68)	1442 (56·70)	535 (21·04)	142 (5·59) (later than 141 B.K.)	268 (23·94)	..	851 (76·46)	68 (27·53)	..	179 (72·46)
3	Production of fertile tillers		854 (33·58)	787 (30·98)	902 (35·47)		Chi = 0·539, P = 0·50 − 0·40			Chi = 1·352, P = 0·30 − 0·20		
							288 (25·73)	659 (58·89)	172 (15·37)	36 (14·57)	117 (47·37)	94 (38·06)
4	Paddy colour		2441 (95·98)	..	102 (4·02)		All normal straw-coloured			199 (80·56)	..	48 (19·44)
5	Presence of awn		2499 (98·27)	17 (0·65)	27 (1·06)		948 (84·71)	128 (11·43)	43 (3·84)	215 (87·06)	14 (5·68)	18 (7·29)
			(Awnless)	(Tipped)	(Awned)		(Awnless)	(Tipped)	(Awned)	(Awnless)	(Tipped)	(Awned)

N.B.—Characters of the F_1 hybrids of these parents were not known as the crosses were done at the Central Rice Research Institute, Cuttack. Figures in brackets show the percentage of population.

later flowering (than late parent, 141 B.K.) which exceeds earlier flowering by about twice the number (than early parent, Rikuu 132).

(iii) *Production of fertile tillers.*—Number of productive tillers in the *japonicas* vary between 15–20 while *indicas* produce about 10 tillers (Table I). F_2 hybrids of these types show a wide range of variation in the capacity for tillering (Table II).

(iv) *Paddy colour.*—*Japonicas* are all straw coloured, while paddy colour of 141 B.K. is brown and 36 B.K. is straw coloured, similar to that of *japonicas*. In Rikuu 132×141 B.K. and in Norin 18×141 B.K., a few of the progenies show brown coloured paddy, though a majority of the hybrids conform to the *japonica* group.

(v) *Awn character.*—All the parents involved in the cross are awnless except 36 B.K., one of the *indica* parents, where the lemma show the rudiments of awn as a slight tip (Table I). It is an interesting feature to note that in all the crosses, awn character expresses itself, though the percentage is small (Table II). 'Tipped' to 'Fully-awned' hybrids were noticed in the population. Similar findings were also recorded by Rajagopaln (*loc. cit.*) in the hybrids, when the parents did not possess this 'awn' character.

TABLE III (*a*)

Showing the percentage of spikelets formed, spikelets empty and flowering duration in the cross

Rikuu 132×141 B.K.

No.	Total No. of spikelets formed	Total No. of empty spikelets	Percentage non-setting	Flowering duration in days
1	240	84	35·00	93
2	238	90	37·82	101
3	148	45	30·41	96
4	211	115	54·50	104
5	286	143	50·00	110
6	159	68	36·48	111
7	223	34	15·25	97
8	146	77	52·74	105
9	306	93	30·39	99
10	183	74	40·44	103
11	169	75	44·34	111
12	239	133	55·65	106
13	148	75	50·68	89
14	106	42	39·62	94
15	263	155	58·93	107
16	86	17	19·77	111
17	147	42	28·65	99
18	183	12	6·57	102
19	229	81	35·37	112
20	293	214	73·03	108

Mean non-setting of spikelets = 41·19%.

(vi) *Setting of spikelets.*—In a number of hybrid progenies was noticed empty spikelets, the percentage varying from 0–100. Fully sterile progenies were not uncommon and very rarely were fully fertile hybrids met with. The data presented in Table III (*a–c*) show that, in a random count of about 50 hybrid progenies, non-setting of spikelets ranges from 6·56–98·09 per cent. Rajagopalan (*loc. cit.*) found that empty spikelets ranged from 21·0–32·3 per cent. in the different crosses. Roy and Subramanyam (1954) while studying the growth performance of *japonica* rice varieties under Indian conditions, found that the percentage of non-setting of spikelets in Rikuu 132, Norin 36 and Norin 18 was 88, 48 and 27 respectively. In view of the low setting of spikelets in two of the *japonica* varieties used as parents, an attempt was made to estimate whether high non-setting of spikelets in Rikuu 132 and Norin 36, had any relation to the non-setting of the spikelets in the hybrids and it was found that there was no relation between the parent and hybrid spikelet settings (Table III, *a–c*).

TABLE III (*b*)

Showing the percentage of spikelets formed, spikelets empty and flowering duration in the cross

Norin 18×36 B.K.

No.	Total No. of spikelets formed	Total No. of empty spikelets	Percentage non-setting	Flowering duration in days
1	210	42	20·00	101
2	304	85	27·96	98
3	196	22	11·23	104
4	178	92	51·69	110
5	264	140	53·03	109
6	169	61	36·09	103
7	208	40	19·23	106
8	176	97	55·12	98
9	168	65	38·69	108
10	308	100	32·47	111
11	268	230	85·82	109
12	212	105	49·53	89
13	169	64	37·87	101
14	214	46	21·49	99
15	194	118	60·83	101
16	311	135	43·41	89
17	118	39	33·51	98
18	174	68	39·81	103
19	309	40	12·95	106
20	268	165	61·57	105

Mean non-setting of spikelets = 40·83%.

The data (Table *a–c*) show that in the common parents, *viz.*, Rikuu 132×141 B.K. and Norin 18×141 B.K., the F_2 progenies of the latter show a higher percentage of non-setting than the former, while the progenies of Norin 18×36 B.K. show a mean of 40·83 per cent. non-setting similar to that of Rikuu 132×141. It is also clear from the

data that there is no relation between non-setting of spikelets and maturity of the hybrids.

TABLE III (*c*)

Showing the percentage of spikelets formed, spikelets empty and flowering duration in the cross

Norin 18 × 141 B.K.

No.	Tolal No. spikelets formed	Total No. of empty spikelets	Percentage non-setting	Flowering duration in days
1	329	215	65·35	101
2	367	294	80·11	98
3	268	176	65·67	104
4	179	111	62·01	89
5	298	283	94·97	96
6	311	206	66·23	103
7	168	89	69·22	110
8	368	254	59·98	107
9	211	183	86·73	104
10	314	299	95·23	101
11	366	359	98·03	98
12	179	86	48·04	99
13	311	210	67·52	99
14	378	265	70·11	104
15	293	180	61·43	107

Mean non-setting of spikelets = 77·51%.

It is of interest to mention that in all the three crosses studied, the parents have white-grained rice, while some of the hybrid progenies of these parents showed coloured grains. No detailed study could, however, be undertaken on this aspect. Similar results were also obtained by Rajagopalan (*loc. cit.*) in the progenies whose parents did not show this grain colour.

F_3 progenies raised under a fertility level of 80 lb. N and 40 lb. P_2O_5 showed that in general the performance of the hybrids was better with respect to seed setting and tillering. The hybrids stood this heavy manuring well without lodging.

SUMMARY

F_2 generation of *japonica-indica* rice hybrids show segregation with respect to many characters like plant height, flowering duration, etc. Some of the interesting features were the expression of 'awn' character and the presence of coloured grains in the progenies where the parents involved did not show these characters. Raising the hybrids in the succeeding generations under increased fertility levels is likely to give better results for selection of types combining these two forms.

Acknowledgement

The authors place on record their sense of gratitude to Dr. N. Parthasarathy, F.N.I., Director, Central Rice Research Institute, Cuttack, for kindly supplying us the hybrid materials for study at the F_2 stage in this Institute.

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SOME UNREPORTED FERNS OF BIHAR

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While making collections of ferns from different parts of Bihar some were found that have not been reported earlier from this area either by Beddome (1892), Haines (1921–25) or by Mooney (1950). It is, therefore, thought proper to record their occurrence in Bihar. A short description of their morphological characters from the actual specimens and their distribution according to Beddome have also been noted down. For the help in the identification of the specimens the author is thankful to the Superintendent, Indian Botanic Gardens, Calcutta, and especially to its Curator, Dr. S. K. Mukerji. In placing the specimens in their respective families, Copeland's (1947) classification has been followed.

Class FILICINEÆ

Order FILICALES

Family PTERIDACEÆ

1. *Dennstædtia appendiculata* (Wall. ex Hook.) J. Sm.—Terrestrial; frond bipinnate, pinnules pinnatifid; veins forked and free as well as simple; rachis hairy; sori round and marginal, each sorus being supplied with a single veinlet; indusium present and formed by the fusion of the true indusium and a minute tooth looking like a cup-shaped or bivalvate structure. Collected from Purnea in October 1953.

Distribution.—Senchal above Darjeeling, 8,500 feet; Lachen Valley, in Sikkim, Nepal; Kumaon Gori Valley, 5,500 feet; Banks of Vishnugunga, above Panchkisar, 8,000–9,000 feet.

Family ASPIDIACEÆ

2. *Athyrium drepanopterum* (Kze.) A. Br.—Terrestrial; frond pinnate, pinnæ nearly cut to the rachis into crenate lobes; veins forked and free; stipe scaly at the base; sori oblong, along the veins and generally on one side of the vein, sometimes on both sides; indusium present and flap like. Collected in October 1952 from Parasnath Hills at a height of 3,000–3,500 feet.

Distribution.—A. drepanopterum is the valid name of *Aspidium eburneum* Wall. which according to Beddome is a synonym of *Lastrea cana* J. Sm. whose distribution according to him is Himalayas near Simla, Sikkim, Yakla, 8,000 feet elevation.

3. *Athyrium macrocarpum* (Bl.) Bedd.—Terrestrial; frond pinnate, lower pinnæ half cut to the rachis, upper pinnæ show crenate margin;

veins forked and free; stipe scaly at the base; sori oblong, along the veins and only on one side of them; indusium present and flap like. Collected in October 1952 from Parasnath Hills at the height of 3,000–3,500 feet.

Distribution.—South India, very common on the Western Mountains, above 3,000 feet; Ceylon; Himalayas, Gurwhal and Bhotan, 2,000–9,000 feet; Khasya; Burma and Malaya Peninsula.

Family POLYPODIACEŒ

4. *Drynaria propinqua* (Wall. ex Mett.) J. Sm.—Epiphytic; frond simple, dimorphic—the scale (bract), sessile leaves for humus collection (Nayar and Kachroo, 1953) and the normal green frond deeply pinnatisect, segments arranged alternately and with broad base and gradually tapering apex, margin obscurely crenate; venation reticulate with included and variously directed free veinlets; stipe scaly below, scales brown in colour with hairy margin; sori round, in two rows one on each side of the midrib of a leaf segment; indusium absent. Only the normal, green, fertile, pinnatisect frond was collected in October 1952 from Parasnath Hills at 3,000–4,000 feet.

Distribution.—Himalayas from Gurwhal to Bhotan, 2,000–7,000 feet; Khasya, very common; Burma; Malaya Peninsula and Java.

The author is thankful to Prof. R. P. Roy, for seminar and laboratory facilities.

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THE HYDROPHYTES OF CUTTACK

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Introduction

Cuttack City is situated between the 20·48′ N. latitude and 85·56′ E. longitude. The climate is tropical and the average annual rainfall is 43 inches. It is a city consisting of 23 square miles. Three sides of the city are surrounded by two big rivers, *i.e.*, the Mahanadi and its branch the Kathjuri. The ground level of the city is almost the same as that of the river beds. The general soil of the city is sandy loam and alluvial at some places. There are a large number of ponds and ditches inside the city. Some of those are used for bathing, fish culture, etc., but a good number of them remain unused by human beings. One canal known as Taldanda canal starts from the Mahanadi river and passes through the city. There is also another small canal which passes through the heart of the city. These canals and most of the ditches and ponds dry up in the summer. These are the main grounds for development of water plants in the city. The growth of innumerable hydrophytes has drawn the attention of many botanists. A systematic work on these aquatic plants has not yet been done by any worker. Haines (1925) or Prain (1903) have not discussed anything regarding the flora of Cuttack. Now as the Botanical Survey of the State has started, much attention has been focussed on these water plants. All of them are not undesirables but on the other hand some of them are useful. The present work gives detailed information regarding the aquatic flora of Cuttack City as far as practicable.

Observations

Aquatic plants generally include plants of various conditions; such as, true aquatics, which are free-floating; submerged or emerged ones, which grow just on the border-line between water and land surfaces; and plants which generally thrive in aquatic conditions. Although aquatic plants grow in an uniform condition and are not much affected by temperature, depth of water, etc., generally some remarkable variations can be noticed due to some factors, *viz.*, transparency or muddiness of water, pH of water and chemical behaviour of the substratum.

The ponds and other sources of aquatic plants were visited in different seasons of the year and plants were collected in their flowering stages. A systematic list is given below showing the name of the plants and the family to which they belong with their flowering seasons and habits. It has been considered convenient to follow the same order as Haines in his *Botany of Bihar and Orissa* for ready reference. The

collected specimens are preserved in the Herbarium of the Botany Department of Ravenshaw College, Cuttack.

ENUMERATION OF THE PLANTS

	Name of the plants	Habit	Flowering season
	Nymphæaceæ		
1.	*Nymphæa rubra* Roxb.	Floating	Sept.–Dec.
2.	*N. esculenta* Roxb.	do.	Oct.–Jan.
3.	*N. stellata* Willd.	do.	March–Sept.
4.	*Nelumbium speciosum* Willd... ..	do.	Feb.–March
	Papilionaceæ		
5.	*Aeschynomene aspera* L.	Emerged	Sept.–Dec.
	Mimosaceæ		
6.	*Neptunia deracea* Lour.	Floating	July–Sept.
	Halorrhagidaceæ		
7.	*Myriophyllum tuberculatum* Roxb. ..	Floating	Sept.–Dec.
	Onagraceæ		
8.	*Jussiaea repens* L.	Floating	Oct.–Dec.
9.	*Trapa bispinosa* Roxb.	do.	July–Aug.
	Umbelliferæ		
10.	*Centella asiatica* (Linn.) Urb. ..	Emerged	Nov.–Jan.
	Gentianaceæ		
11.	*Limnanthemum cristatum* Griseb. ..	Floating	Jan.–Dec.
	Convolvulaceæ		
12.	*Ipomoea reptans* L.	Floating	Jan.–Dec.
	Scrophulariaceæ		
13.	*Limnophila heterophylla* Bentb. ..	Emerged	Oct.–Jan.
14.	*L. gratioloides* Br.	do.	Oct.–Feb.
	Lentibulariaceæ		
15.	*Utricularia stellaris* L.f.	Submerged	Oct.–Jan.
	Acanthaceæ		
16.	*Asteracantha longifolia* Nees. ..	Emerged	Oct.–Jan.
	Alismaceæ		
17.	*Alisma plantago* L.	Emerged	Oct.–Jan.
18.	*Sagittaria sagittifolia* L.	do.	Nov.–Jan.

Name of the plants	Habit	Flowering season
Naiadaceæ		
19. *Aponogeton monostachyon* L.	Submerged	Jan.–Dec.
20. *Potamogeton indicus* Roxb.	do.	Sept.–Jan.
Hydrocharitaceæ		
21. *Hydrilla verticillata* Casp.	Submerged	July–Sept.
22. *Vallisneria spiralis* L.	do.	Jan.–May
23. *Ottelia alismoides* Pers.	do.	July–Dec.
Araceæ		
24. *Pistia stratoites* L.	Floating	Oct.–Jan.
Lemnaceæ		
25. *Lemna polyrrhiza* L.	Floating	Oct.-Jan.
Cyperaceæ		
26. *Cyperus articulatus* L.	Floating	April–July
27. *Scirpus articulatus* L.	Emerged	Dec.–Jan.
Gramineæ		
28. *Sacciolepis myosuroides* Comb.	Emerged	Aug.–Nov.
29. *Panicum repens* L.	do.	July–Dec.
Pontederiaceæ		
30. *Monochoria hastata* Solm.	Emerged	Jan.–Nov.
31. *M. vaginalis* Presl.	do.	Jan.–Aug.
32. *Eichornia crassipes* Solm.	do.	March–July
Marsiliaceæ		
33. *Marsilia quadrifoliata* L.	Floating	Oct.–March

Discussion

This is a very preliminary work and the investigation of the flora of Cuttack is in rapid progress. Though Haines (1925), Prain (1903), Mooney (1950) and Bal (1942) have done some work regarding certain parts of Orissa states, they have not discussed much about the flora of Cuttack or the costal districts. Now the main aim of our work is to list all these plants of Orissa not only for the study of Botany but also to discover rare, economical and medicinal plants. Now that the Botanical Survey of India has started, we hope that our work will also fall within the plans of the B.S.I.

Summary

Preliminary work has been done to find out the hydrophytes of the Cuttack. It has been found that the number of aquatic

monocotyledonous is greater than that of the aquatic dicotyledonous and families like Hydrocharitaceæ, Cyperaceæ, Gramineæ and Pontederiaceæ are dominating.

Acknowledgment

This is a part of the work done in connection with the Botanical Survey of Orissa entrusted to Prof. B. Samantarai by the Board of Scientific and Industrial Research, Orissa. Our thanks are due to the said Board for financial help and to Prof. B. Samantarai for kind supervision and encouragement. We are also grateful to Mr. C. M. Bastia of this Department for his encouragement.

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THE CLAVARIACEÆ OF THE MUSSOORIE HILLS—III

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(Received for publication on December 22, 1955)

This paper is intended to record more Clavariaceæ from the Mussoorie Hills as a part of the study of the Cryptogamic Flora of that region (Thind and Anand, 1956; Corner, Thind and Anand, 1956*). Of the seven Clavarias described, one belongs to the Clavariadelphus-series, and six belong to the Clavaria-series. *Clavariadelphus mirus* (Pat.) Corner, *Clavulinopsis aurantio-cinnabarina* (Schw.) Corner and *Clavulinopsis alcicornis* (Zoll. et Mor.) Corner are new records for India. *Clavulinopsis biformis* (Atk.) Corner var. *elongata* var. nov. and *Clavulina bessonii* (Pat.) Corner var. *incarnata* var. nov. are described here as new varieties. All the specimens are deposited in the Herbarium of the Punjab University.

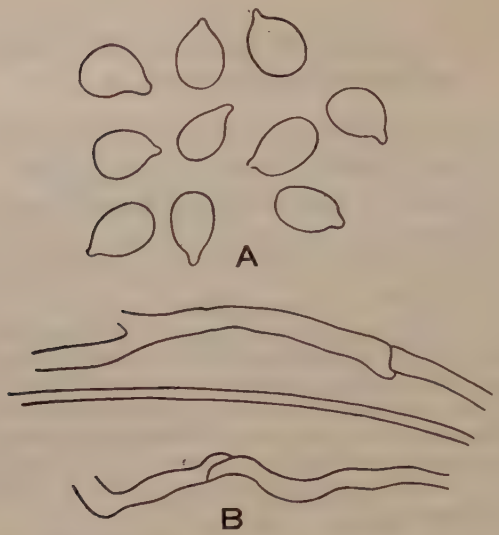
The classification as proposed by Corner, 1950, in his *Monograph of Clavaria and Allied Genera*, has been followed in the present study.

Clavariadelphus-series

15. *Clavariadelphus mirus* (Pat.) Corner

Fructifications gregarious, solitary, rarely sub-cæspitose, erect, large-sized, radial, trunk indistinct, simple, tough, smooth, glabrous, light brown or camel-brown coloured, lower portion being light dull yellow, up to 22·5 cm. tall and up to 1·5 cm. broad at the top and up to 0·9 cm. broad at the base. Trunk indistinct, lighter coloured, light dull yellow, narrower than the clubs above, smooth. Clubs simple, very rarely forked only once at the top, solid, cylindrical below while usually flattened and longitudinally rugulose in the upper part, younger specimens usually cylindrical even in the upper portion. Apices concolorous, fertile, blunt, rounded, often flattened, and swollen. Flesh cream coloured or pale yellow, turning vinaceous brown on bruising and not so on mere exposing. Taste bitter, smell inparticular. *Hymenium* spreading all over except the basal dull yellowish stem-like portion, thickening, up to 87 μ broad. *Basidia* clavate, light brown, 8–12 μ broad. Sterigmata mostly 4, sometimes 2–3, massive, large, straight or incurved, 7·4–11·2 μ long. *Basidiospores* subhyaline, broadly ellipsoid, obovate or pyriform, papillate, papilla up to 1·2 μ long, smooth, aguttate, 8·6–10·8 × 7–8·6 μ. *Hyphæ* monomitic, hyaline, thin-walled, branched, usually inflated but some narrow and uninflated, septate, septa at long intervals, clamped, clamps abundant and present almost at all septa, 1·7–10·5 μ broad, hyphal cells very long (up to 206 μ or more) (Pl. VIII, Fig. 1; Text-Fig. 1, A–B).

* Five new species and two new varieties of Clavarias are described in this paper.



TEXT-FIG. 1. *Clavariadelphus mirus* (Pat.) Corner. A, Basidiospores, ×880 ; B, Clamped hyphæ, ×380.

Collected on soil under Oak Forest (*Quercus incana* Roxb.), Dhobi Khud, Mussoorie, August 28, 1953, **46**.

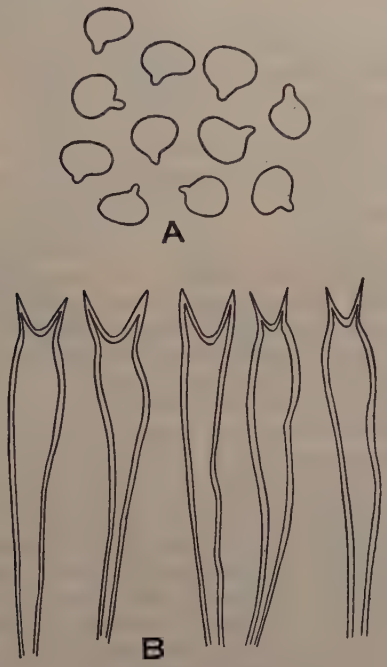
The species is clearly related to *Clavariadelphus pistillaris* (Fr.) Donk but differs in the tall narrow shape and brown colour of the fruit bodies and the short wide spores.

CLAVARIA-SERIES

16. *Clavulinopsis fusiformis* (Fr.) Corner

Fructifications solitary, cæspitose, erect, medium-sized, radial, trunk present, simple, fleshy, smooth, glabrous, orange at the top, fading to yellow lower down, and finally white in the region of trunk, the whole cæspitose cluster up to 6·5 cm. tall and up to 3·5 cm. broad, individual clubs up to 6·5 cm. tall and up to 0·4 cm. broad. Trunk cylindrical, not grooved, one-third of the length of clubs, clearly demarcated by its white colour. Young clubs cylindrical, mature clubs become grooved and often flattened, a single groove running along the middle of the club, mature clubs slightly hollow within. Apices acute, concolorous. Flesh paler concolorous. Taste and smell inparticular. *Hymenium* spread all over except the white trunk, thickening, up to 95 μ thick. *Basidia* clavate with a long tapered base, often becoming thick-walled and persisting in the hymenium, subhyaline, with large globules, 5–11 μ broad. Sterigmata mostly 2, large, stout and straight, 4·5–10·6 μ long. *Basidiospores* subhyaline, obovate, papillate, papilla usually eccentric, smooth, aguttate, a single large greenish-yellow guttule observed in some cases, 4·2–7·4×6·2–9·8 μ,

papilla 1–2 μ long. *Hyphæ* monomitic, hyaline, thin-walled, usually parallel, sparsely branched, usually inflated, some narrow hyphæ are uninflated, septate, septa at short intervals, some hyphæ, especially the narrow ones, secondarily septate, clamps absent, narrow uninflated hyphæ 3·5–5·2 μ broad and with cells up to 95 μ long, broader inflated hyphæ 7–16 μ broad and with cells up to 52 μ long, often much shorter (Pl. VIII, Fig. 2; Text-Fig. 2, A–B).



TEXT-FIG. 2. *Clavulinopsis fusiformis* (Fr.) Corner. A, Basidiospores, ×880; B, Long tapered and thick-walled basidia, ×880.

Collected on soil under Oak Forest, The Park, Mussoorie, August 25, 1953, **47**.

Except for the absence of clamps and the presence of predominantly 2-spored basidia the present fungus closely resembles *Clavulinopsis fusiformis* (Fr.) Corner. The present fungus is the only one lacking clamps among more than a hundred species of the genus *Clavulinopsis* Van Ov. reported so far. The absence of clamps in this case may be connected with the predominantly 2-spored (? haploid) state of the fruit body.

This fungus also closely resembles *Clavulinopsis amœna* (Zoll. et Mor.) Corner but is easily distinguished from the latter by the possession of a large (1–2 μ long) apiculus to the spore.

The presence of predominantly 2-spored basidia and the absence of clamps would indicate that this fungus belongs to the genus *Clavulina* Schroet. However, as in *Clavulinopsis*, the basidia in this fungus possess long-tapered base and the straight sterigmata and often become thick-walled and persist in the hymenium. *Clavulina*, on the other hand, has a subcylindric basidium, eventually becoming septate, and curved sterigmata.

17. *Clavulinopsis biformis* (Atk.) Corner var. *elongata* var. nov.

Usque 9 cm. longa, solitaria vel gregaria vel cæspitosa, sordide alba: sporis 4·3–5×3–3·5 μ, 1-guttulatis: hyphis fibulatis: terrestris, Chakrata Toll, Mussoorie, India, September 2, 1953, **48**.

Up to 9 cm. long, solitary, gregarious, sometimes cæspitose, dirty white; spores 4·3–5×3–3·5 μ, uniguttate: terrestrial, Chakrata Toll, Mussoorie, India, September 2, 1953, **48**.

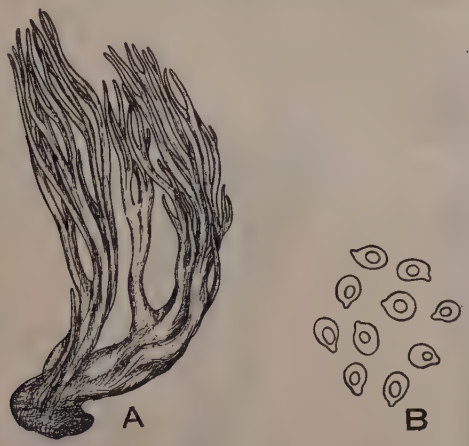
Fructifications solitary, gregarious, sometimes cæspitose, erect, medium-sized, radial, trunk present or absent, profusely branched, firm-fleshy, pubescent below, smooth and glabrous above, dirty white, up to 9 cm. tall and up to 3 cm. broad. Trunk when present up to 3·5 cm. long, pubescent, cylindrical, like the primary branches and of the same width. Branching profuse, starting right from the base or from a distance of 3·5 cm., dichotomous, branches unequal, in alternating planes, often fused together, primary branches up to 3 mm. broad, ultimate branchlets in unequal pairs and up to 1 cm. long. Apices concolorous and acute to rounded. Flesh concolorous. Taste and smell inparticular. *Hymenium* spread all over except the basal pubescent portion, thickening strongly but is largely sterile except on the young branches, up to 103 μ broad. *Basidia* small, clavate, 28–35 ×4·7–6 μ. Sterigmata 4, slightly incurved, 3–5 μ long. *Basidiospores* subhyaline to hyaline, small, obovoid to subglobose, papillate, smooth, uniguttate, guttule small, filling about one-fourth of the spore cavity, 4·3–5×3–3·5 μ. *Hyphæ* monomitic, hyaline, thin-walled, branched, mostly inflated but narrow ones uninflated, septate, septa at short intervals in the inflated hyphæ and at longer intervals in the narrow ones, clamped, clamps common, H-connections present, inflated hyphæ 5·2–10·3 μ broad while narrow uninflated hyphæ 1·7–5·2 μ broad, hyphal cells of inflated hyphæ up to 146 μ long, those of narrow uninflated hyphæ up to 361 μ long (Text-Fig. 3, A–B).

Collected on humous soil under Oak Forest, Chakrata Toll, Mussoorie, September 2, 1953, **48**.

The hymenium of this fungus thickens strongly but is largely sterile except on the young branches.

This fungus resembles *Clavulinopsis biformis* (Atk.) Corner in all respects except that its fruit bodies are up to 9 cm. tall in contrast to 4 cm. as the maximum length recorded so far for the fruit bodies of *C. biformis*. Therefore, it is made a variety of *C. biformis* on the basis of its large fruit bodies, as has also been suggested by Corner

(personal correspondence, 1955). The varietal name *elongata* is proposed here to indicate the large fruit bodies.



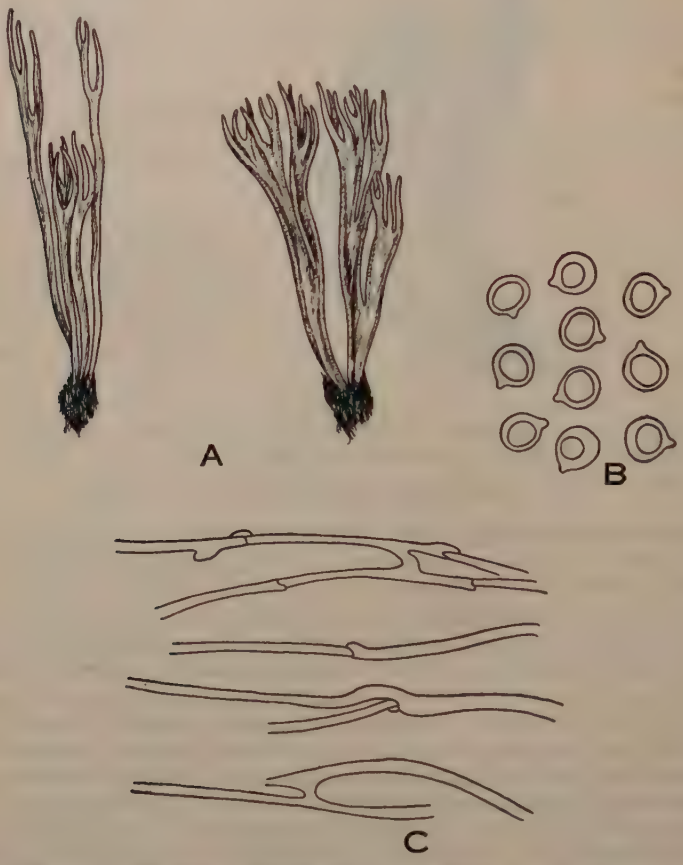
TEXT-FIG. 3. *Clavulinopsis biformis* (Atk.) Corner var. *elongata* var. nov. A, Fructification, ×1; B, Basidiospores, ×880.

18. *Clavulinopsis corniculata* (Fr.) Corner

Fructifications gregarious, cæspitose, erect, medium-sized, radial, trunk usually present, sometimes absent, sparsely branched, fleshy, smooth, glabrous, dull ochraceous, up to 7 cm. tall, the whole cæspitose cluster up to 3 cm. broad, individual fructifications up to 0·5 cm. broad. Trunk radial or flattened and grooved, narrower than the fructifications above, concolorous, up to 5 cm. long and up to 0·3 cm. broad. Branching sparse, from 1–4 times, dichotomous, may start right from the base when trunk is absent. Branches unequal, divergent, or divaricate with wide lunate axils, in alternating planes, primary branches often flattened and grooved, upper ones usually cylindrical, internodes long, ultimate branchlets in pairs, slightly incurved, 1–10 mm. long. Apices concolorous and acute. Flesh lighter coloured. Taste slightly bitter, smell inparticular. Numerous rhizomorphic mycelial strands given out from the base of fructifications; several separate mycelial hyphæ also given out from the base. They are septate, abundantly clamped, slightly darker and slightly thickened. *Hymenium* spread all over including the trunk, thickening, up to 79 μ broad. *Basidia* clavate, 6–8 μ broad. Sterigmata mostly 4, slightly incurved, 4–10 μ long. *Basidiospores* subhyaline, globose, papillate, papilla 1–1·2 μ long, smooth, uniguttate, guttule from small to large filling one-half or more of the spore cavity, 4–7 μ broad. *Hyphæ* monomitic, hyaline, branched, thin-walled, mostly slender, narrow and uninflated, septate, septa at long intervals, clamped, H-connections present but sparse, 1·8–7 μ broad, hyphal cells very long (Text-Fig. 4, A–C).

Collected on soil under Oak Forest, Chakrata Toll, Mussoorie, August 30, 1953, **49**.

The species is recognized by the yellow fruit bodies with sparse branches, divaricate with wide lunate axils and globose uniguttate spores (4–7 μ. wide).

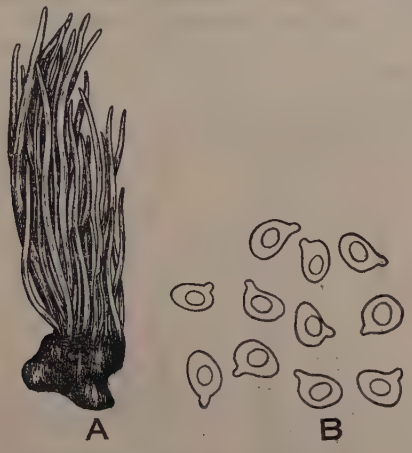


TEXT-FIG. 4. *Clavulinopsis corniculata* (Fr.) Corner. A, Two fructifications, ×1; B, Basidiospores, ×880; C, Hyphæ clamped and with H-connections, ×380.

19. *Clavulinopsis aurantio-cinnabarina* (Schw.) Corner

Fructifications gregarious, densely cæspitose, erect, small-sized, slender, radial, trunk present, simple, fleshy, smooth, glabrous, deep orange red, up to 5·5 cm. tall, the cæspitose clusters up to 2 cm. broad, individual clubs very thin, mostly 0·5–2 mm. broad, some old ones very much flattened with the flattened side up to 5 mm. broad but the edge being only about 1 mm. thick. Trunk indistinct, paler concolorous, may be narrower than the club above or not, up to 2 cm. long. Clubs cylindrical, slender, mature and old ones may become flattened and grooved, apices concolorous, subacute or rounded. Flesh deep orange red, not fading. Taste and smell inparticular. *Hymenium*

spread all over except the trunk, up to 68 μ thick, small, granular crystal-like bodies abundantly present in the hymenium. *Basidia* clavate, orange coloured, 4·2–7 μ broad. Sterigmata mostly 4, sometimes 2–3, incurved, 3·7–7 μ long. *Basidiospores* paler orange coloured, obovate to subglobose, papillate, papilla 1–2 μ long, smooth, uniguttate, guttule filling about one-third of the spore cavity, 7–7·4×4·2–7 μ. *Hyphæ* monomitic, orange coloured, both narrow and slightly broad, thin-walled, uninflated, broader ones slightly inflated, septate, septa at short to longer intervlas, at longer intervals in narrow hyphæ and at short intervals in broader hyphæ, clamped, narrow hyphæ usually very much convoluted while broader ones usually straight, 1·8–7 μ broad (Text-Fig. 5, A–B).



TEXT-FIG. 5. *Clavulinopsis aurantio-cinnabarina* (Schw.) Corner. A, Fructification, ×1; B, Basidiospores, ×880.

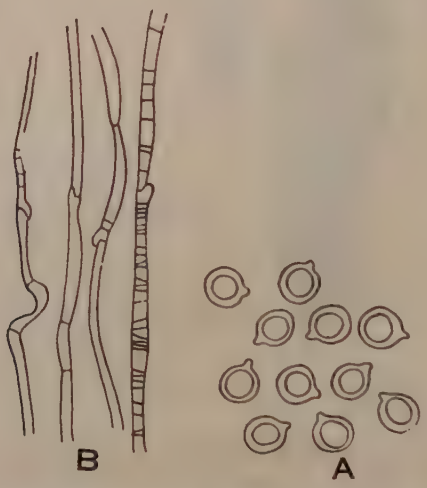
Collected on soil under Oak Forest, Chakrata Toll, Mussoorie, August 20, 1953, **50**.

The species is easily known from the simple, deep orange red fructifications, pale orange, subglobose to obovoid, uniguttate spores (7–7·4×4·2–7 μ), orange coloured hyphæ, and hymenium with many small crystals.

20. *Clavulinopsis alcicornis* (Zoll. et Mor.) Corner

Fructifications solitary, cæspitose, erect, small-sized, radial, trunk usually present, much branched, fleshy, smooth, glabrous, yellowish buff coloured, up to 5 cm. tall and up to 3·5 cm. broad. Trunk up to 1 cm. long and up to 4 mm. broad, radial, sometimes lacking. Branching dichotomous, branches lax, unequal, in alternating planes, internodes long. Each fructification branches at the most 3–5 times and the branches become thinner and thinner upward as is usual of other Clavariaceæ. Primary branches up to 4 mm. broad, ultimate branch-

lets long, 0·2–3·9 cm. long, usually in pairs like a pair of tongs but also found solitary. Apices acute, concolorous. Flesh lighter coloured. Taste and smell inparticular. *Hymenium* spread all over, up to 88 μ broad. *Basidia* clavate, 7–9 μ broad. Sterigmata 4, slightly incurved, 3·5–8·8 μ long. *Basidiospores* globose, papillate, papilla 1–1·5 μ long, hyaline to subhyaline, smooth, uniguttate, guttule almost completely filling up the spore cavity, 5·3–6·9 μ in diameter. *Hyphæ* monomitic, hyaline to subhyaline, brown in a mass, thin-walled or slightly thick-walled, septate, secondary septa observed in several hyphæ, secondary septa profusely developed or sparse, not inflated but swollen and beaded at places. Hyphæ often irregular in outline varying from merely wavy to deeply constricted so as to give a beaded appearance, swollen in the region of beads as well as in the portion with wavy margin. Hyphæ are clamped, clamps present on every primary septum, 1·8–6 μ, or more in diameter (Pl. VIII, Fig. 3; Text-Fig. 6, A–B).



TEXT-FIG. 6. *Clavulinopsis alcicornis* (Zoll. et Mor.) Corner. A, Basidiospores, ×880.; B, Secondarily septate and clamped hyphæ, ×380.

Collected on soil under Oak Forest, Dhobi Khud, Mussoorie, August 18, 1953, **51**.

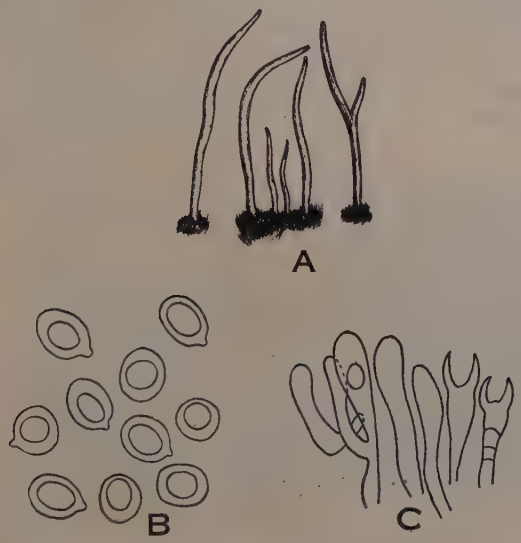
The species shows close resemblance to *Clavulinopsis corniculata* (Fr.) Corner but is easily differentiated by the more numerous branches, and the secondarily septate, irregular often wavy to beaded hyphæ.

21. *Clavulina bessonii* (Pat.) Corner var. *incarnata* var. nov.

Usque 1·6×0·1 cm., simplicia, raro monoramosa, stipitate, incarnata: stipite—2×0·8 mm., pallide-incarnata: sporis 7–7·4 μ, 1-guttatis: hyphis fibulis præditis: terrestris, Dhobi Khud, Mussoorie, India, September 19, 1953, **52**.

Up to 1·6×0·1 cm., simple, rarely branched only once, trunk present, pink: trunk—2×0·8 mm., lighter pink coloured, spores 7–7·4 μ in diameter, uniguttate: hyphæ provided with clamps: terrestrial, Dhobi Khud, Mussoorie, India, September 19, 1953, **52**.

Fructifications gregarious, erect, small-sized, radial, slender, trunk present, simple, or rarely branched only once, fleshy, smooth, glabrous, pink up to 1·6 cm. tall and up to 1 mm. broad. Trunk up to 2 mm. long and up to 0·8 mm. broad, lighter pink coloured. Clubs are usually bent, or sometimes straight. Apices blunt and concolorous. Taste and smell inparticular. *Hymenium* spread all over except the lighter coloured trunk, thickening, up to 81 μ broad. *Basidia* clavate, subhyaline, contents granular, secondarily septate after spore discharge, 3·5–7 μ broad. Sterigmata 2, incurved, 5·3–7 μ long. *Basidiospores* hyaline, globose to subglobose, papillate, smooth, uniguttate, guttule large, filling nearly three-fourth of the spore cavity, 7–7·4 μ in diameter. *Hyphæ* monomitic, hyaline, thin-walled, branched, somewhat inflated, septate, septa at short intervals and hence hyphæ small-celled, clamped, clamps abundant and nearly at all septa, may look like cells gliding over one another, hyphal cells 3·5–8·8×17·5–70 μ (Text-Fig. 7, A–C).



Text-Fig. 7. *Clavulina bessonii* (Pat.) Corner var. *incarnata* var. nov. A, Simple and rarely branched fructifications, ×2; B, Basidiospores, × 880; C, Basidia, becoming secondarily septate after spore discharge, ×880.

Collected on soil amid mosses under an Oak Forest, Dhobi Khud, Mussoorie, September 19, 1953, **52**.

This fungus closely resembles *Clavulina bessonii* (Pat.) Corner, except that its fruit bodies are pink in contrast to the white fruit bodies of *C. bessonii*. Accordingly, this fungus is made a pink-coloured

variety (var. *incarnata* var. nov.) of *C. bessonii*, as has also been suggested by Corner (personal correspondence, 1955).

Acknowledgements

The writers are deeply indebted to Mr. E. J. H. Corner, F.R.S., of the Botany School, Cambridge, England, for valuable criticism and help in the identification of the species of Clavarias and Prof. P. N. Mehra for providing facilities and encouragement. They are also thankful to Mr. B. Khanna, for making illustrations of some of the fructifications.

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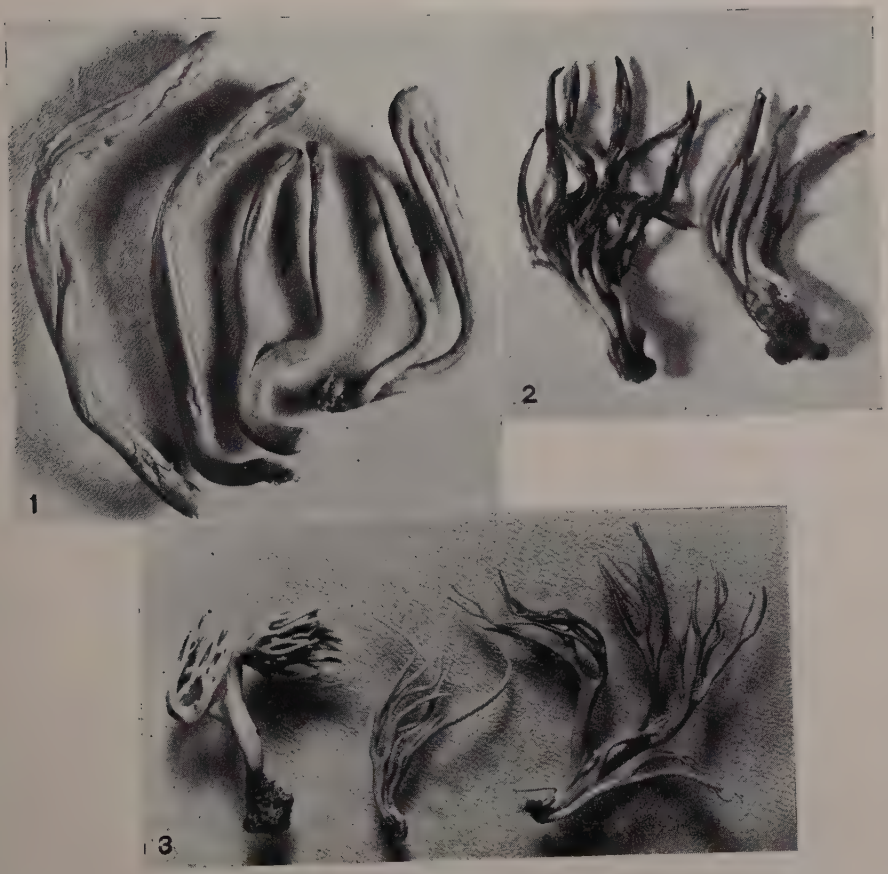
Explanation of Plate

Figs. 1–3. Fig. 1. *Clavariadelphus mirus* (Pat.) Corner. Fig. 2. *Clavulinopsis fusiformis* (Fr.) Corner. Fig. 3. *Clavulinopsis alcicornis* (Zoll. et Mor.) Corner.



FIGS. 1–3

K. S. Thind and G. P. S. Anand

THE GAMETOPHYTES OF *LYCIUM EUROPÆUM* LINN.

By T. C. Jain

Department of Botany, Government College, Ajmer, India

(Received for publication on December 13, 1955)

Introduction

Lycium europæum is a spinous shrub found in Merwara and Rajasthan, India. Although it belongs to Solanaceæ, in floral structure, it resembles Convolvulaceæ. Its morphological study has been undertaken with the belief that it may show some transitory features connecting Solanaceæ and Convolvulaceæ.

Hofmeister (1858) described the mature embryo-sac in *Hyoscyamus orientalis*, *Scopolina atropoides* and *Salpiglossis picta*. Jönsson (1881) studied the development of embryo-sac and found that in *Saracha jaltomato* the megaspore mother cell forms a linear tetrad of megaspores, the innermost of which develops into an eight-nucleate 'Polygonum type' of embryo-sac. The same type of development has been described in a number of plants of this family (Guignard, 1882; Souèges, 1907; Palm, 1922; Svensson, 1926; Banerji, 1931; Bhaduri, 1932; Goodspeed, 1947; and Walker, 1955). Contrary to the above, Nanetti (1912) and Young (1923) found that the embryo-sac development follows that of 'Lilium-type' in *Solanum muricatum* and *S. tuberosum* respectively and Modilewski (1935) reports a bisporic eight-nucleate 'Scilla-type' of embryo-sac in *Nicotiana glauca*.

Material and Methods

The material for this study was collected from Adarsh Nagar Hills and Foy Sagar Road, Ajmer, and fixed in formalin-acetic-alcohol and acetic-alcohol. Immature buds were placed in the fixing fluid as such while the tips of the older buds were trimmed to ensure better fixation. In the case of open flowers the sepals, petals and occasionally the stamens were removed and only the ovaries were fixed. The customary processes of dehydration and infiltration were followed. Transverse and longitudinal sections, 8–12 microns in thickness, were cut and stained in safranin and fast-green. The earlier developmental stages up to two-nucleate embryo-sac were obtained in transverse sections. Later stages, however, were found in the longitudinal sections, 10–12 microns in thickness. This is due to the changes in the orientation of the ovule during its development.

Microsporogenesis and Male Gamet ophyte

The five epipetalous initials of the stamens arise as blunt processes. These undifferentiated masses of cells soon become bilobed, each lobe bearing a pair of loculi. The anther is basally attached to its filament.

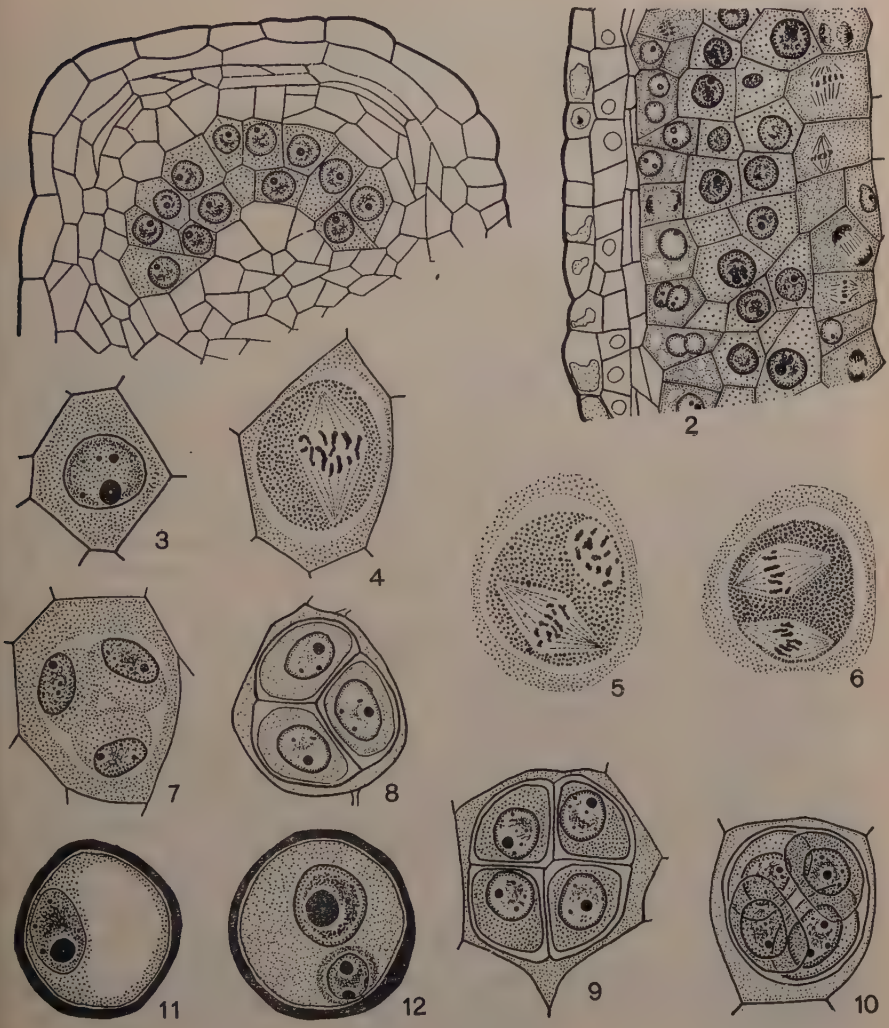
Unlike the genus *Solanum* where the anther opens by apical pores, the mature anther dehisces by longitudinal slits.

The archesporium differentiates as a plate of hypodermal cells which divide periclinally to form primary parietal cells and primary sporogenous cells. The former divide anticlinally and periclinally to form four-wall layers (Fig. 1) the innermost of which functions as tapetum, the sub-epidermal layer acts as the endothecium and the remaining two form the middle layers (Fig. 2). The primary sporogenous cells divide further and ultimately differentiate as microspore mother cells (Fig. 2).

The endothecium is uniseriate; towards the connective, however, it is many seriate. The protoplast of the epidermal cells shrink at the shedding time of the pollen grains and their outer tangential walls develop cuticular dentations. The inter-locular tissue in each lobe disorganises resulting in the line of dehiscence in the form of a longitudinal slit.

The innermost layer of the parietal tissue differentiates as the glandular tapetum (Fig. 2). About the time the mother cells are in the resting stage, the tapetal cells become completely filled with dense cytoplasm and stain densely. The nuclear division in the tapetum takes place by normal mitosis and the tapetal cells become bi-nucleate (Fig. 2). Later as the tapetal cells enlarge a large vacuole appears in the cytoplasm. The tapetum is absorbed during the formation and maturation of the pollen grains. Its remnants, however, persist for some time, completely disappearing at the shedding stage of the pollen grains. The tapetal cells derived from the anther tissue towards the connective are more conspicuous in size (Fig. 2).

The sporogenous tissue is arc-shaped in each lobe (Fig. 1). The mother cells develop gelatinous sheaths around them, inside their original cell wall. The first meiotic division produces a dyad and the second, a tetrad of microspores (Figs. 3–6). Different types of microspore tetrads result (Figs. 8–10) due to the differences in the orientation of the spindles at the second meiotic division. There is not much synchronization in the divisions of mother cells of a loculus during the meiotic divisions. Cytokinesis takes place by furrows which appear at the periphery and grow inward till they meet at the centre, dividing the protoplast into four microspores (Fig. 7). The microspores separate and development of the exine takes place. A vacuole develops inside the pollen grain which displaces the nucleus towards the wall (Fig. 11). The pollen grains are smooth-walled, spheroidal and tri-forate. The division of the microspore nucleus results in a vegetative and a generative cell (Fig. 12). The pollen grains are shed at the two-celled stage. It has been observed in smears that before division the generative cell becomes very much elongated and is accommodated in the pollen grain in the form of a sickel-shaped body. In the pollen tube, however, it becomes almost straight. Instances were also noted therein, where the pollen tubes from different pollen grains coiled around each other. This suggests that the pollen grains had germinated *in situ*.



FIGS. 1–12. Fig. 1. T.S. of part of anther showing microspore mother cells. Fig. 2. L.S. of anther showing microspore mother cells, tapetum and wall layers. Fig. 3. Microspore mother cell. Figs. 4–6. Meiosis I and II, note metaphasic spindles with different orientations in Figs. 5 and 6. Fig. 7. Cytokinesis in microspore mother cell by furrowing. Figs. 8–10. Tetrahedral, isobilateral and decussate tetrads. Fig. 11. Uninucleate pollen grain. Fig. 12. Bi-celled pollen grain. Figs. 1, 2, ×63. Figs. 3–12, ×766.

The vertical section of the glandular stigma has been observed to be abundantly filled with densely staining and sufficiently long pollen tubes.

Ovule

The ovary is bilocular and its carpellary margins meet only incompletely in the centre. A bulky placenta is absent and there are not many ovules, showing thereby resemblance with Convolvulaceæ.

The development of the ovule conforms to the type found in most of the Sympetalæ. It initiates its development at the time when the microspore mother cells are being formed. The ovular papillæ arise as minute protuberances and as they grow, the more pronounced growth on one side results in their anatropic form. The ovule is tenuinucellate and unitegmic (Figs. 15, 17); a single vascular strand extends through the funiculus up to the chalaza.

The hypodermal archesporial cell differentiates very early along with the primordia of the integument (Fig. 13). The integument is 2–3 cells thick at the time when the mother cell is distinguishable. Prior to heterotypic division, it becomes 4–5 cells thick and at the dyad stage begins to arch over the nucellus forming a micropyle, 4–5 cells long. Frequently the degeneration of the dyad and the tetrad has been noted, which probably is due to an insect biting the flower. The ovules in an injured ovary almost always show the signs of degeneration of the sporogenous tissue. Later the micropyle becomes a long narrow and curved canal (Figs. 17–19).

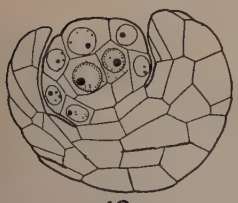
The embryo-sac during its development, beginning at the micropylar end, completely absorbs the nucellus (Figs. 20, 24, 26), leaving a few degenerated masses, which stain darkly towards the chalazal region. The inner integumentary epidermis assumes a tapetum-like appearance rather early (Fig. 18). Its cells become radially elongated and have glandular contents, prominent nuclei and nucleoli. The cells of this endothelium remain always uninucleate. The presence of integumentary tapetum enclosing the embryo-sac is a characteristic feature of the Solanaceæ (Bhaduri, 1935 and Souèges, 1907), and is found in most of the Sympetalæ. As the embryo-sac enlarges in dimensions, the cells at the chalazal end become gradually absorbed (Figs. 24, 26). A hypostase could not be observed at the chalazal end (*cf.* Walker, 1955).

A weakly developed glandular obturator is organized from the epidermal cells of the placenta.

Megasporogenesis

As in most of the Sympetalæ, the archesporium directly functions as the megaspore mother cell (Fig. 14) and is distinguishable from the rest of the cells by its dense cytoplasm and a prominent nucleus. A pair of archesporial cells of integumentary origin has been reported in addition to the hypodermal archesporial cell by Bhaduri (1932) in *S. melongena.*

The nucleus of the young megaspore mother cell prior to its division occupies a more central position. The mother cell elongates and divides. The metaphasic spindle lies in the centre of the cell (Figs. 15,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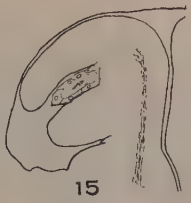
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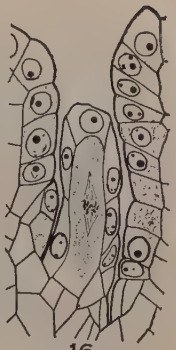
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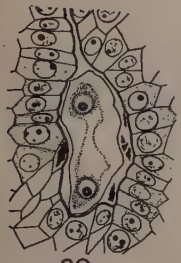
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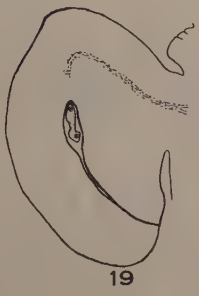
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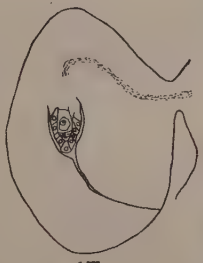
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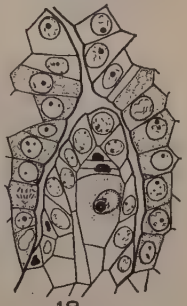
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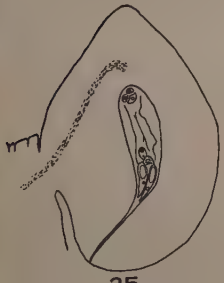
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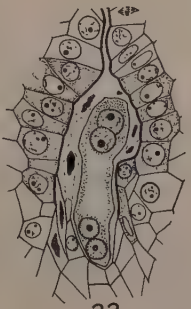
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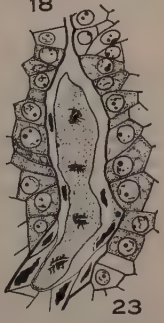
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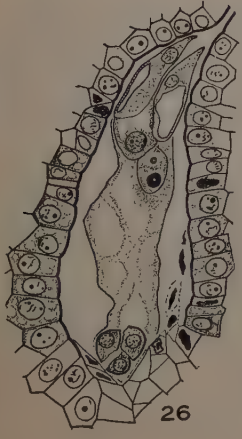
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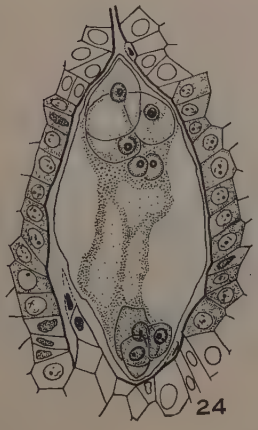
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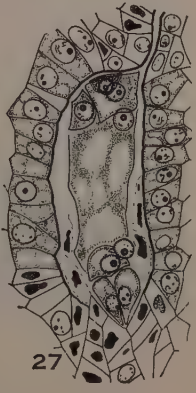
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FIGS. 13–27. Fig. 13. Young ovule showing two enlarged cells in the nucellus. Fig. 14. Megaspore mother cell. Fig. 15. Ovule showing megaspore mother cell in metaphase. Fig. 16. Same, a portion magnified. Fig. 17. Massive integument and chalazal functioning megaspore. Fig. 18. Same, a portion magnified with endothelial cells. Fig. 19. Ovule with two-nucleate embryo-sac. Fig. 20. Same, a portion magnified showing disintegrated nucellar cells. Fig. 21. Ovule with four-nucleate embryo-sac. Fig. 22. Four-nucleate embryo-sac. Fig. 23. Same, dividing. Fig. 24. Mature embryo-sac. Fig. 25. Ovule, embryo-sac with fused polars. Fig. 26. Same, magnified. Fig. 27. Embryo-sac with inverse polarity. Figs. 13, 14, 16, 18, 20, 22, 23, 24, 26, 27, ×366; Figs. 15, 17, 19, ×116.

16). The mother cell divides and forms a linear tetrad of megaspores. The chalazal megaspore functions and the other three degenerate, and are found in a degenerated state to cap over the functioning one (Figs. 17, 18). The functioning megaspore enlarges in size and becomes vacuolated.

EMBRYO-SAC

The nucleus of the embryo-sac mother cell divides and the two nuclei are displaced towards the poles with the appearance of a central vacuole (Fig. 20). The nuclei of the two-nucleate embryo-sac divide at their respective poles. The chalazal end of the four-nucleate embryo-sac buries itself deep in the chalaza (Figs. 22–23). It passes into an eight-nucleate 'Polygonum-type' of embryo-sac. Goodspeed (1947) reports an embryo-sac with more than eight-nuclei in *N. tabacum*. Twin embryo-sacs in an ovule have been recorded in *S. melongena* (Bhaduri, 1932) and *S. tuberosum* (Young, 1922).

The pear-shaped synergids which lie side by side elongate and slightly project into the micropyle (Fig. 26). The filiform apparatus was not observed and the beak of the synergid is also indistinguishable (Fig. 24). The egg usually becomes enlarged and the vacuole occupies a large area of the egg cell while its nucleus is accommodated in the thin cytoplasm at its base (Fig. 24). The egg may become elongated reaching very near the secondary nucleus (*cf.* Cooper, 1931; Walker, 1955). The synergids degenerate rather early.

In one case the egg apparatus had disintegrated while the antipodals were found in a healthy condition. Of the three antipodals, normally two are found to lie side by side while the third one is placed below them. The antipodals are semilunar in shape. They are filled with dense cytoplasm. The expansional activity of the embryo-sac is more pronounced at the chalazal end.

The polars fuse near the egg before fertilization (Fig. 26). The earlier fusion of the polars has also been reported by Cooper (1931) for *Lycopersicum esculentum* and by Guignard (1902) for *Datura lævis*. A case of inversion of the embryo-sac, with a characteristic egg apparatus at the chalazal end, has been noted (Fig. 27) (*cf.* Goodspeed, 1947). This embryo-sac has three antipodal-like cells at the micropylar end.

Summary

In the anther, the archesporium is in the form of a plate in each lobe. The sub-epidermal wall layer differentiates as the endothecium and the innermost as secretory tapetum. There are two middle layers. The tapetal cells divide by normal mitosis. The sporogenous tissue is arc-shaped. There is no synchronization in the division of the mother cells of a loculus. The formation of the microspore tetrad by furrowing is of simultaneous type. The pollen grains are smooth-walled, triforate and spheroidal. They are shed at the two-celled stage.

The ovules are anatropous, unitegmic and tenuinucellate. The embryo-sac completely absorbs the nucellus and the inner integumentary layer differentiates as the 'Integumentary tapetum'. The placental tissue proliferates as a glandular obturator. The hypodermal archesporial cell directly functions as the megaspore mother cell and divides to form a linear row of four megaspores of which the chalazal functions. The development of the female gametophyte conforms to the monosporic eight-nucleate Polygonum type of embryo-sac. A mature embryo-sac with reverse polarity has also been observed. The expansional activity of the chalazal end of the embryo-sac is striking.

Acknowledgement

I am thankful to Professor B. Tiagi, for guidance and to Principal V. V. John, for research facilities.

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STUDIES IN THE FAMILY EUPHORBIACEÆ

I. The Gametophytes of *Chrozophora rottleri* A. Juss.

By Gyanendra Sharma

D.A.V. College, Ajmer

(Received for publication on December 13, 1955)

Introduction

Considering the inconsistency in the reproductive structures and the large number of species included in the family Euphorbiaceæ, the studies on the family made so far, are rather insufficient to ascertain its correct position in a natural system of classification. Moreover, there are contrasting reports which need further work and confirmation. As two different types of embryo-sac development have been reported for *Chrozophora rottleri* A. Juss., the present study was undertaken with the hope to add some more useful information. This work is the first of the series and is in accordance with the proposed scheme for further studies in this family.

Schnarf (1931) has reviewed the previous work on the family Euphorbiaceæ and eight types of embryo-sac recorded for this family have been tabulated by Maheshwari (1942). The Polygonum type of embryo-sac is of common occurrence in this family.

Recently Polygonum type of embryo-sac development has been reported in *Chrozophora obliqua* and *Chrozophora prostrata* var. *parvifolia* (Kapil, 1955; 1956). In *Chrozophora rottleri* (Srivastava and Agarwal,* 1953), a bisporic type of development has been found. The present investigation, however, reveals that the development in this species is of Polygonum type and confirms the recent report by Kapil (1956).

Material and Methods

Formalin-acetic-alcohol was used as fixative for fixing buds and flowers of different ages. The presence of dense stellate hairs on the ovary wall and on the calyx caused a great deal of difficulty in cutting serial microtome sections. Hence, as far as possible, the ovules and anthers of different ages were removed from the buds and processed in the usual manner. Sections of anthers and ovules were cut eight to twelve microns and ten to sixteen microns thick, respectively. The sections of ovules were stained in safranin—fast-green and in Heidenhain's iron hæmatoxylin and those of anthers in Delafield Hæmotoxylin and in Heidenhain's iron hæmotoxylin.

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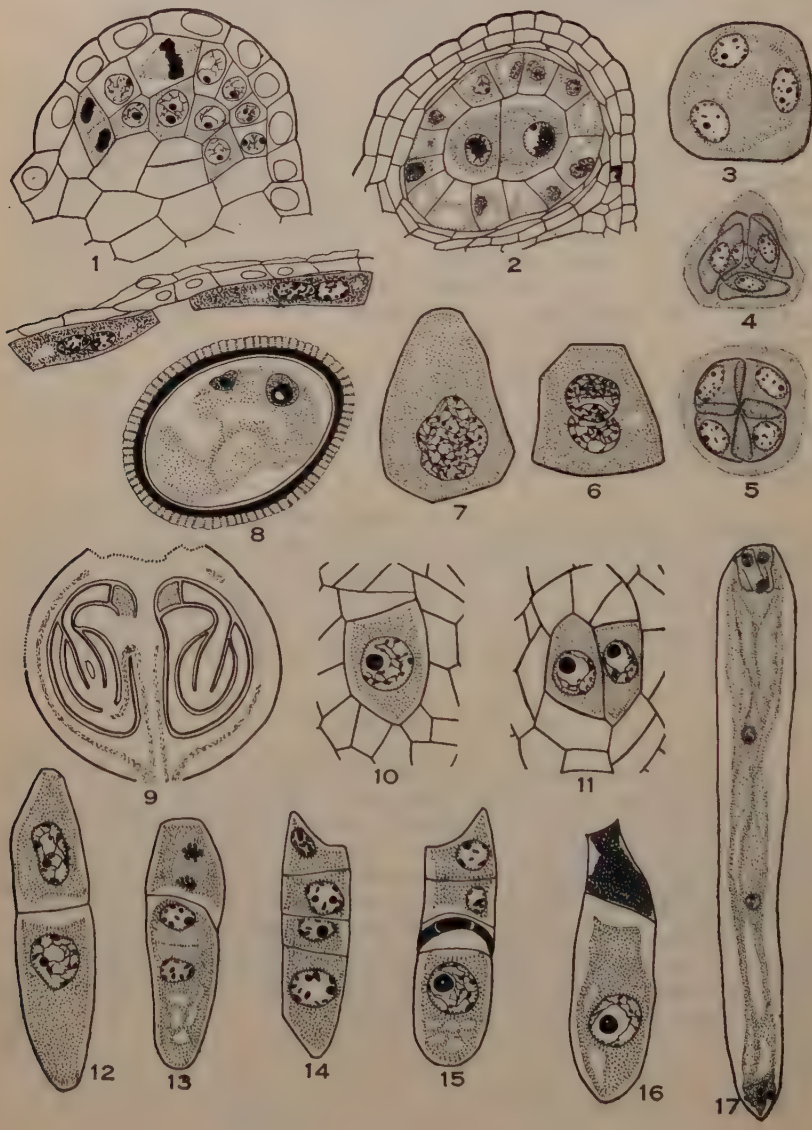
* Quoted from Kapil, 1955.

Microsporogenesis and Male Gametophyte

The archesporium, as seen in cross-section, consists of three to five hypodermal cells. These divide periclinally to give rise to an inner primary sporogenous layer and an outer primary parietal layer (Fig. 1). The latter divides to form the hypodermal endothecium, two middle layers and the tapetum (Fig. 2). The sporogenous layer undergoes a few divisions to give rise to pollen mother cells.



FIGS. 1–17. Fig. 1. T.S. anther showing primary sporogenous and primary parietal layers, × 633. Fig. 2. T.S. anther showing microspore mother cells, tapetum and wall layers, × 433. Fig. 3. Tetrahedrally arranged microspore nuclei, × 633. Fig. 4. Microspore tetrad, ×633. Fig. 5. Decussate tetrad, × 633. Figs. 6–7. Binucleate and polyploid tapetal cells, × 633. Fig. 8. Mature bicelled pollen grain, tapetal cells persisting, × 633. Fig. 9. L.S. ovary showing two ovules, obturator and vascular supply, × 38. Fig. 10. Megaspore mother cell, × 833. Fig. 11. Two megaspore mother cells, × 833. Fig. 12. Dyad, × 833. Fig. 13. Same, dividing, × 833. Fig. 14. Linear tetrad, × 833. Fig. 15. Same, third megaspore from micropylar end degenerating, × 833. Fig. 16. Functioning megaspore, × 833. Fig. 17. Mature embryo-sac, × 266.

The cells of endothecium do not show any radial fibrous thickenings, so characteristic of the angiosperms (Fig. 8). The inner middle layer degenerates earlier by the end of the meiotic divisions in the pollen mother cells, while the remnants of the outer are present till the formation of the mature pollen grains. The uninucleate cells of the tapetal layer become binucleate at a time when the pollen mother cells are in early prophase. This layer becomes conspicuous due to enlargement and vacuolation of the cells (Fig. 2). At this stage it may detach from the rest of the wall layers and later on its cells separate from each other, but curiously enough, persist till the formation of the mature pollen grains (Fig. 8). The tapetal nuclei show divisions and fusions resulting in polyploid nuclei (Figs. 6, 7). Similar observations have been recorded for *Pedilanthus tithymaloides* and *Gelonium multiflorum* (Banerji, 1951). A multi-nucleate tapetum is reported in *Euphorbia esula* (Kapil, 1955).

The young pollen mother cell is surrounded by a distinct dense sheath of mucilage which develops in between the protoplast and the parent cell wall. It persists till the formation of microspore tetrads and their liberation (Figs. 3, 4). Division of microspore mother cells is simultaneous and cytokinesis takes place by furrowing (Fig. 3). Microspores are arranged tetrahedrally (Fig. 4). Decussate (Fig. 5) and isobilateral tetrads also occur.

The microspore develops an exine and intine and increases considerably in size. Vacuolation starts from the periphery, ultimately forming a large central vacuole and pushing thereby the nucleus towards the periphery where it divides mitotically to form a large vegetative and a small generative cell (Fig. 8). The mature bicelled pollen grain is octocolporate, reticulate and sphæroidal.

OVULE

The ovules are slightly hemianatropous, bitegmic and crassinucellate. Primordia for the inner integument appear when the megaspore mother cell is developing and is soon followed by the primordia for the outer integument. An early origin of the inner integument appears to be a common feature in this family and this has been reported by other workers also (Maheshwari, 1942; Banerji, 1951 and Srivastava, 1952). However, the outer integument overgrows the inner at the dyad stage of megasporogenesis. The inner integument is thicker and its apex is attenuated.

A true micropyle is not formed because of the conspicuously long and slender nucellar beak which is also found in other genera of this family. It projects far beyond the micropyle, curving and facing towards the placental obturator (Fig. 9), which is composed of long glandular cells. The presence of an obturator is a common feature for this family. The vascular supply to the ovule terminates at the chalaza (Fig. 9).

Megasporogenesis and Female Gametophyte

The hypodermal archesporium is found in very young ovules. The megaspore mother cell is pushed deep down in the nucellus by the repeated division of the parietal layers (Fig. 10). Divisions in nucellar epidermal cells (Kapil, 1956) were not observed in my material. The mother cell enlarges considerably and shows a large nucleus. Two mother cells lying side by side have also been observed (Fig. 11) and this feature is often recorded in this family. The megaspore mother cell undergoes heterotypic divisions to form a linear tetrad of megaspores (Figs. 12 to 14) of which the chalazal develops further (Fig. 16). A triad with an upper dyad cell as in *Chrozophora obliqua* and *Chrozophora prostrata* var. *parvifolia* (Kapil, 1955, 1956) was not observed in my material. The development of a linear tetrad of megaspores is clear and so I am unable to corroborate the findings of Srivastava and Agarwal (1953) who report a bisporic embryo-sac in this species. Degeneration of megaspores starting from the micropylar end is usual in the family. However, in *Chrozophora rottleri* the megaspore above the functional chalazal one, invariably degenerates first (Fig. 15) as in *Euphorbia hirta* (Kajale and Rao, 1942).

The functioning megaspore enlarges and small vacuoles appear on the polar sides of the nucleus (Fig. 16). By three more successive divisions it forms an eight-nucleate embryo-sac of the Polygonum type (Fig. 17). The embryo-sac elongates considerably. The beaked synergids overlap the egg which in turn lies in between them at a different level. The antipodal cells are variously arranged, usually two of them lie side by side while the third below them (Fig. 17). They degenerate prior to fertilization.

Fusion of polar nuclei takes place in the vicinity of egg.

Summary

No fibrous thickenings are seen in the endothecium. The polyploid tapetum is of the secretory type. The mature bicelled pollen grain is octocolporate, reticulate and sphæroidal.

The ovule is crassinucellate, bitegmic and slightly hemianatropous and has a projecting nucellar beak facing the placental obturator. Development of the embryo-sac follows the Polygonum type and not the bisporic type.

Acknowledgements

I am thankful to Professor B. Tiagi, for guidance, to Principal V. V. John, for research facilities, and the Government of the State

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A CONTRIBUTION TO THE KNOWLEDGE OF FRESH-WATER DIATOMACEÆ OF SOUTH-WESTERN INDIA

I. Fresh-Water Diatoms of Dharwar

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(Received for publication on October 2, 1955)

Introduction

There are only a few accounts dealing with fresh-water diatoms of India available and practically none so far covering the south-west region of the Peninsula. The following account is based on some collections in this region, at Dharwar.

Topography and the Climate of Dharwar

Dharwar, in the State of Bombay, is situated on the Poona-Bangalore line of the Southern Railway. The town proper lies at 15° 27′ latitude and 75° 6′ longitude on a plateau of medium height which varies between 2,400–2,544′ above the mean sea-level. It has a fairly cool climate and an average annual rainfall of 32″.

Places of Collection

The material for this investigation was collected from the garden reservoirs of the Karnatak College—Dharwar, by the author when he was attached to the said College during July–August 1949. He was particularly interested to know the nature of the floating frothy masses and encrustations in the reservoirs. An examination of the material revealed a mass of diatoms—particularly the Cymbellas embedded in gelatinous matrix and the tangled masses of some blue-green algæ. More material was then collected and preserved in 5–6% of commercial formalin. A few casual samples of algæ were also collected by the author from Kilgeri and Someswar tanks and preserved likewise during the same period. Due to unforeseen circumstances the collections, however, could not be examined then and there. The material was later studied at the Ismail Yusuf College, Jogeswari—Bombay, during 1949–51, and at the Rajaram College—Kolhapur, during 1951–55.

Features of the Material

An interesting feature of the material from the garden reservoirs is the preponderance of *Cymbella cymbiformis* (Ag. ?) Kütz. and its varieties. They were found embedded in the gelatinous floating flakes and as encrustations in the reservoirs. Associated with these forms

the following occur in good numbers: *Achnanthes microcephala* Kütz. v. *typica* A. Cl., *A. minutissima* (Kütz.) Grun. v. *genuina* A. Cl., *Stauronies legumen* Ehr., *Anomœoneis serians* (Bréb.) Cl. v. *modesta* A. Cl., *A. brachysira* (Bréb.) Grun. v. *genuina* A. Cl., *A. brachysira* (Bréb.) Grun. f. *subacuminata* A. Cl., *Navicula cryptocephala* Kütz. v. *subsalina* Hust., *Gomphonema parvulum* (Kütz.) V. H. v. *genuina* Mayer, *G. parvulum* v. *subellipticum* Cleve, *G. dharwarensis* sp. nov. and *Nitzschia amphibia* Grun. v. *genuina* Mayer. The other forms included in this account were present in lesser numbers. The noteworthy point regarding *Cymbella cymbiformis* and its varieties is that none of these were as large as the European specimens. It may perhaps be due to their warmer habitat in this country.

The material from Kilgeri tank resembled somewhat that of the garden reservoirs in the College; however, *Melosira granulata* (Ehr.) Ralfs. v. *typica* A. Cl., *Gomphonema subapicatum* Frit. and Rich and *Rhopalodia gibba* (Ehr.) O. Müll. v. *genuina* A. Cl., were present in numbers.

The Someswar tank material was rich in *Cymbella ventricosa* Kütz. v. *genuina* A. Cl., *Gomphonema subapicatum* Frit. and Rich, *G. montanum* Schum. v. *acuminatum* Mayer, *Rhopalodia gibba* (Ehr.) O. Müll. v. *genuina* A. Cl and *Nitzschia amphibia* Grun. v. *genuina* Mayer. The other forms occurred as stray forms.

In all 44 forms including a new species and a new variety, have been recorded from this area representing 18 genera.

The forms in this account are mainly arranged according to Hustedt (1930), the identification being carried out with the help of Cleve-Euler's monograph (1951–55) and other accounts.

BACILLARIOPHYTA (DIATOMEÆ)

A.	Order	**CENTRALES**
I.	Suborder	DISCINEÆ
1.	*Family*	*COSCINODISCACEÆ*
(*a*)	*Sub-family*	MELOSIROIDEÆ
	Genus	**Melosira** Agardh 1824

1. *Melosira granulata* (Ehr.) Ralfs. v. *typica* A. Cl.

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—I, p. 25, fig. 15 *a–b*. *M. granulata* (Ehr.) Ralfs—Van Heurck, *Treat. Diat.*, p. 444, pl. 19, fig. 621; Hustedt, *Bacil.*, p. 87, fig. 44; Tiffany and Britton, *Alg. Illinois*, p. 221, pl. 59, fig. 667.

Frustules cylindrical, united in short or long chains, 9–18 μ long, 6–12 μ in diameter, end cells with short and long spines and furrows. Cell surface with 8–10 rows of aerioles in 10 μ and 10–12 aerioles in 10 μ, aerioles arranged in straight and parallel rows on the end cells and spirally on the others.

(*b*) *Sub-family* COSCINODISCOIDEÆ

Genus **Cyclotella** Kutzing, F.T. 1834

2. *Cyclotella stelligera* Cl. and Grun.

Hustedt, *Bacil*, p. 100, fig. 65; Venkataraman, *S.I. Diat.*, p. 298, fig. 10; Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—I, p. 43 fig. 52.

Frustules in chains, rectangular in the girdle view. Valves discoid, 10–15 μ in diameter with radiating striæ; middle portion with stellate structure around a central punctum, striæ 11–12 in 10 μ.

3. *Cyclotella meneghiniana* Kütz. v. *genuina* A. Cl.

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—I, p. 48, fig. 63 *a*. *C. Meneghiniana* Kütz.—Van Heurck, *Treat. Diat.*, p. 447, pl. 22, fig. 656; Hustedt, *Bacil.*, p. 100, fig. 67.

Frustules with undulated walls in the girdle view. Valves discoid, 11–29 μ in diameter with apparently smooth or radially punctate central field. Marginal striæ 7–9 in 10 μ, thick and radial.

4. *Cyclotella meneghiniana* Kütz. v. *genuina* A. Cl. f. *binotata* Grun.

(Fig. 1)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—I, p. 48, fig. 63 *c*. *C. meneghiniana* Kütz.—Van Heurck, *Treat. Diat.*, p. 447, pl. 22, fig. 656.

Frustules with undulated walls in the girdle view. Valves discoid, 15–25 μ in diameter with the radially punctate central field having two large distinct punctæ. Marginal striæ 8–9 in 10 μ, thick and radial.

B. Order **PENNALES**

I. Sub-order ARAPHIDINEÆ

1. *Family* *FRAGILARIACEÆ*

(*a*) *Sub-family* FRAGILARIOIDEÆ

Genus **Fragilaria** Lyngbye 1819

5. *Fragilaria rumpens* (Kütz.) Carlson v. *fragilarioides* (Grun.) A. Cl.

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—II, p. 42, fig. 352, *b*. *Synedra rumpens* Kütz. v. *fragilarioides* Grun.—Hustedt, *Bacil.*, p. 156, fig. 178; Gonzalves and Gandhi, *Diat. Bombay and Salsette*—I, p. 129, fig. 22.

Frustules in continuous chain. Valves linear-lanceolate with constricted slightly capitate ends, 38–52 μ long, 3–3·3 μ broad. Pseudoraphe narrow. Central area large. Striæ 10–12 in 10 μ, coarse and distinct.

Genus **Synedra** Ehrenberg 1830

6. *Synedra ulna* (Nitz.) Ehr. v. *amphirhynchus* (Ehr.) Grun.

Van Heurck, *Treat. Diat.*, p. 311, pl. 10, fig. 414; Hustedt, *Bacil.*, p. 154, fig. 167; Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—II, p. 62, fig. 382 *g*.

Frustules elongated with widened truncate ends in the girdle view. Valves narrow, linear-lanceolate, bent in the middle with capitale ends, 175–255 μ long and 5–6 μ broad. Pseudoraphe very narrow. Striæ slender but distinct 9–10 in 10 μ.

7. *Synedra acus* Kütz. v. *genuina* Mayer

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—II, p. 64, fig. 385 *a–c*. *S. acus* (Kütz.) Grun.—Van Heurck, *Treat. Diat.*, p. 311, pl. 10, fig. 420; *S. acus* Kütz.—Hustedt, *Bacil.*, p. 155, fig. 170; Tiffany and Britton, *Alg. Illinois*, p. 237, pl. 63, fig. 720.

Valves weakly silicified, elongated, narrowly lanceolate, gradually tapering towards the poles, 77–133 μ long and 3·3–4 μ broad. Pseudoraphe very narrow. Central area large rectangular reaching the sides. Striæ fine those bordering the central area do not reach the centre, 13–14 in 10 μ.

II. Sub-order MONORAPHIDINEÆ
1. *Family* *ACHNANTHACEÆ*
(*a*) *Sub-family* COCCONEOIDEÆ
Genus **Cocconeis** Ehrenberg 1838

8. *Cocconeis placentula* Ehr. v. *euglypta* (Ehr.) Grun.

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—III, p. 8, fig. 492 *e–f*. *C. placentula* Ehr. v. *euglypta* (Ehr.) Cl.—Hustedt, *Bacil.*, p. 190, fig. 261; Iyengar and Subrahmanyan, *Fossil Diat.*, p. 229, figs. 7–8.

Valves broadly elliptical, 18–24 μ long and 11–12 μ broad. Valves with raphe has small roundish central area. Striæ 20–23 in 10 μ, fine but distinctly punctate, radial and interrupted by two concentric hyaline zones near the margins. Rapheless valve with narrow pseudoraphe. Striæ 17–18 in 10 μ, radial, interrupted by several longitudinal undulated hyaline bands.

Genus **Achnanthes** Bory 1822
Sub-genus *Microneis*

9. *Achnanthes microcephala* Kütz. v. *typica* A. Cl.

(Figs. 2–3)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—III, p. 40 fig. 568 *a–d*; *A. microcephala* Kütz.—Van Heurck, *Treat. Diat.*, p. 281, pl. 8, fig. 332. Hustedt, *Bacil.*, p. 198, fig. 273.

Frustules small, linear, bent in the girdle view. Valves narrow, linear-lanceolate with broadly rounded capitate ends, 15–20 μ long and 3–3·5 μ broad. Valve with raphe has narrow axial area and rounded central area. Striæ 26–32 in 10 μ, radial; rapheless valve with narrow pseudoraphe, small central area and slightly radial striæ 30–35 in 10 μ.

10. *Achnanthes minutissima* (Kütz.) Grun. v. *genuina* A. Cl.

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*,—III, p. 40 fig. 567 *a–f. A. minutissima* Kütz.—Hustedt, *Bacil.*, p. 198, fig. 274; Tiffany and Britton, *Alg. Illinois*, p. 242, pl. 64, fig. 727.

Frustules small, linear and bent in the girdle view. Valves narrow, linear-lanceolate with broadly rounded ends, 17–31 μ long and 3–3·7 μ broad. Central area somewhat wider on the raphe valve. Striæ fine and slightly radial, 28–30 in 10 μ.

III. Sub-order BIRAPHIDINEÆ
1. Family *NAVICULACEÆ*
(*a*) *Sub-family* NAVICULOIDEÆ
Genus **Mastogloia** Thwaites 1856

11. *Mastogloia smithii* Thwaites v. *lacustris* Grun.

(Figs. 4–5)

Van Heurck, *Treat. Diat.*, p. 154, pl. 2, fig. 61; Hustedt, *Bacil.*, p. 217, fig. 316.

Frustules rectangular in the girdle view with two longitudinal septa having several chambers in a row. Valves linear-elliptical with constricted somewhat broadly rostrate ends 27–37 μ long and 10–11 μ broad. Raphe thin and straight. Axial area narrow, linear; central area fairly wide quadrate to roundish. Interseptal chambers rectangular to quadrate, almost uniform 1·2–1·5 μ wide in a row near the margins. Striæ 16–18 in 10 μ, radial and distinctly punctate.

Cleve-Euler has treated this form synonymous with *M. lacustris* Grun. v. *antiqua* (Schum.) A. Cl. (Cleve-Euler, *Diat. von Schwed. u. Finn.*—III, p. 60, fig. 609 *d, g*) but in indices the same has been referred to *M. lacustris* v. *alpina* Brun. Under this condition the present author fails to refer his form to any one given by Cleve-Euler.

Genus **Diploneis** Ehrenberg 1840

12. *Diploneis subovalis* Cleve

Venkataraman G., *S.I. Diat.*, p. 322, fig. 74, pl. 17, figs. 3–4; Gonzalves and Gandhi, *Diat. Bombay and Salsette*—II, p. 254, fig. 87 *a*.

Valves broadly elliptical 31–35 μ long and 18–19 μ broad. Raphe thin enclosed between the capitate horns. Costæ radial distinctly capitate under a low focus alternate with double rows of distinct punctæ 9–9·5 in 10 μ and rows of punctæ 16–18 in 10 μ. Axial field

with a row of punctæ in groups separated by a hyaline space from the inter-costal rows of punctæ.

Genus **Stauroneis** Ehrenberg 1843

13. *Stauroneis legumen* Ehr.

(Fig. 6)

Van Heurck, *Treat. Diat.*, p. 161, pl. 1, fig. 59; Hustedt, *Bacil.*, p. 260, fig. 419.

Valves linear with triudulate margins and constricted, broadly rostrate ends, 14–28 μ long and 4–6 μ broad. Polar septa short and distinct. Raphe thin and straight with distinct central pores. Axial area narrow; central area somewhat a large linear stauros. Striæ slightly radial, about 30 in 10 μ, very fine and indistinctly punctate.

Genus **Anomœoneis** Pfitzer 1871

14. *Anomœoneis serians* (Bréb.) Cl. v. *modesta* A. Cl.

(Figs. 7–8)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—III, p. 197, fig. 918 *c–d.*

Valves rhombic-lanceolate to narrowly rhombic-lanceolate with acute ends, 22–32 μ long and 5–6 μ broad. Raphe thin and straight with closely placed central pores. Axial area narrow, linear; central area fairly large and quadrate. Striæ 27–30 in 10 μ, slightly radial, fine but distinctly punctate, crossed by 3–5 longitudinal, undulated hyaline bands 10–12 in 10 μ.

15. *Anomœoneis brachysira* (Bréb.) Grun. v. *genuina* A. Cl.

(Fig. 9)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—III, p. 198, fig. 919 *a–b. A. serians* (Bréb.) Cl. v. *brachysira* (Bréb.) Hust. f. *thermalis* (Grun.) Hust.—Hustedt, *Bacil.*, p. 264, fig. 428.

Valves small, rhombic-lanceolate with feebly narrowed, produced, broadly rounded ends, 22–26 μ long and 6·6 μ broad. Raphe thin and straight with closely set central pores. Axial area narrow; central area moderate, roundish. Striæ 25–28 in 10 μ, radial fine but distinctly punctate, interrupted by a few longitudinal wavy hyaline bands.

16. *Anomœoneis brachysira* (Bréb.) Grun. f. *subacuminata* A. Cl.

(Fig. 10)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—III, p. 198.

Valves rhombic-lanceolate with somewhat constricted, shortly produced ends, 23–33 μ long and 5–6 μ broad. In all other features like the type.

This form agrees well with the type described by Cleve-Euler, who has however not given a figure. Of several specimens which I

have examined, I found their ends distinctly constricted and shortly produced as stated by Cleve-Euler.

Genus **Navicula** Bory 1822

Section—*Naviculæ orthostichæ* Cleve

17. *Navicula cuspidata* Kütz. v. *conspicua* Venkat.

Venkataraman, G., *S. I. Diat.*, p. 325, figs. 83, 88; Gonzalves and Gandhi, *Diat. of Bombay and Salsette*—III, p. 342, fig. 110.

Valves broadly lanceolate with narrowed produced rounded ends, 121–150 μ long and 32–35 μ broad. Raphe thin and straight with hook-like central pores. Axial area narrow, linear. Longitudinal striæ 9–12 in 10 μ, coarse and more widely set in the middle than at the margins; transverse striæ 14–16 in 10 μ, parallel and almost perpendicular to the middle line.

18. *Navicula pseudocuspidata* nov. nom. v. *rostrata* v. nov.

(Fig. 11)

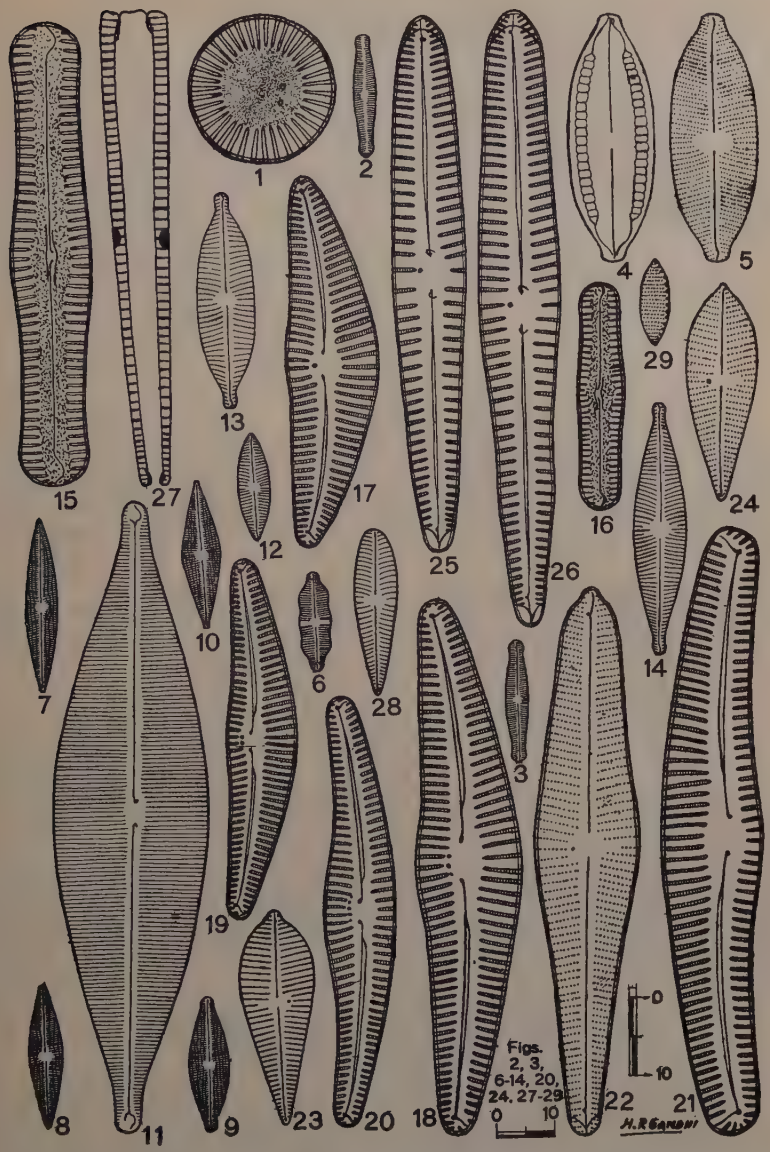
Valvæ rhombio-lanceolatæ vel late lanceolatæ, apicibus constrictis, producti atque rotundati. Raphe tenuis atque recta, poris centralibus hamosimilibus ornata. Area axialis angusta, linearis; area centralis aliquantum evoluta. Striæ longitudinales nullæ; striæ transversales parallelæ, indistincte punctatæ atque perpendiculares in lineam medium. Frustula 88–111 μ longa, 22–27 μ, lata, striæ transversæ 14–16 in 10 μ.

Habitat.—Atque dulcis. Lacu in horto.

Valves rhombic-lanceolate to broadly lanceolate with constricted produced rounded ends. Raphe thin and straight with hook-like central pores. Axial area narrow, linear; central area slightly developed. Longitudinal striæ absent; transverse striæ parallel, indistinctly punctate and perpendicular to the middle line. Frustules 88–111 μ long and 22–27 μ broad with transverse striæ 14–16 in 10 μ.

Habitat.—Fresh-water. Garden reservoirs.

This form agrees well with Krishnamurthy's *Navicula cuspidata* Kütz. f. *indica* Kri. (Krishnamurthy—*Diat. S. I.*, p. 367, fig. 30), in having no longitudinal striæ and in other respects, except that the ends in this form are prominently produced and rounded. The feature of longitudinal striæ so characteristic of *N. cuspidata* Kütz., being absent in these forms—I do not think it proper to retain them under the said species. I, therefore, propose for Krishnamurthy's form the status of a new species as *N. pseudocuspidata*, and create my form a new variety of it. The present form cannot be referred to *N. halophila* (Grun.) Cl. (Hustedt, *Bacil.*, p. 268, fig. 436) for the presence of hook-like central pores which is a feature of *N. cuspidata*.



FIGS. 1–29. Fig. 1. *Cyclotella meneghiniana* Kütz. v. *genuina* A. Cl. f. *binotata* Grun. Figs. 2–3. *Achnanthes microcephala* Kütz. v. *typica* A. Cl. Figs. 4–5. *Mastogloia smithii* Thwaites v. *lacustris* Grun. Fig. 6. *Stauroneis legumen* Ehr. Figs. 7–8. *Anomœneis serians* (Bréb.) Cl. v. *modesta* A. Cl. Fig. 9. *Anomœoneis brachysira* (Bréb.) Grun. v. *genuina* A. Cl. Fig. 10. *Anomœoneis brachysira* (Bréb.) Grun. f. *subacuminata* A. Cl. Fig. 11. *Navicula pseudocuspidata* nov. nom. *rostrata* v. nov. Fig. 12. *Navicula cryptocephala* Kütz. v. *subsalina* Hust. Fig. 13. *Navicula viridula* Kütz. v. *capitata* Mayer. Fig. 14. *Navicula salinarum*.

Grun. v. *intermedia* (Grun.) Cl. Fig. 15. *Pinnularia acrosphæria* (Bréb.) W. Sm. f. *undulata* Cl. Fig. 16. *Pinnularia acrosphæria* (Bréb.) W. Sm. v. *minor* Cl. Fig. 17. *Cymbella cymbiformis* (Ag. ?) Kütz. v. *unipuncta* A. Cl. Figs. 18-19. *Cymbella cymbiformis* (Ag. ?) Kutz. v. *jimboi* (Pant.) A. Cl. Fig. 20. *Cymbella cymbiformis* (Ag. ?) Kütz. v. *multipunctata* A. Cl. Fig. 21. *Cymbella cymbiformis* (Ag. ?) Kütz. v. *nerei* (Pant.) A. Cl. Fig. 22. *Gomphonema sub-apicatum* Fritsch & Rich. Fig. 23. *Gomphonema augur* Ehr. v. *genuinum* Mayer. Fig. 24. *Gomphonema montanum* Schum. v. *acuminatum* Mayer. Figs. 25–26. *Gomphonema dharwarensis* sp. nov. Fig. 27. *Gomphonema dharwarensis* sp. nov.—girdle view. Fig. 28. *Gomphonema olivaceum* (Lyng.) Kütz. v. *balticum* Cl. Fig. 29. *Nitzschia amphibia* Grun. v. *acutiuscula* Grun.

Section—*Naviculæ lineolatæ* Cleve

19. *Navicula cryptocephala* Kütz. v. *subsalina* Hust.

(Fig. 12)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—III, p. 154, fig. 813 *i, j, n.*

Valves small, lanceolate with acutely rounded ends, 17–26 μ long and 5–6 μ broad. Raphe thin and straight. Axial area narrow, linear; central area small, roundish. Striæ 14–16 in the middle and up to 18 in 10 μ at the ends, lineate, radial in the middle and convergent at the ends.

This form agrees well with the type described by Cleve-Euler but differs from *N. cryptocephala* v. *veneta* (Kütz.) Grun. (Hustedt, *Bacil.*, p. 295, fig. 497 *a*), in having more acute ends.

20. *Navicula viridula* Kütz. v. *capitata* Mayer

(Fig. 13)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—III, p. 151, fig. 805 *f, g.*

Valves linear-elliptical with somewhat produced capitate rounded ends, 35–38 μ long and 9 μ broad. Raphe thin and straight. Axial area narrow, linear; central area moderately wide, quadrate. Striæ 9–13 in 10 μ, distinctly lineate, radial in the middle and convergent at the ends.

21. *Navicula salinarum* Grun. v. *intermedia* (Grun) Cl.

(Fig. 14)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—III, p. 159, fig. 820 *b–c.*

Valves lanceolate with produced capitate ends, 38–41 μ long and 7–8 μ broad. Raphe thin and straight. Axial area narrow, linear; central area large. Striæ 14–16 in 10 μ, lineate, radial and curved in the middle and convergent at the ends, short and long striæ alternate in the middle.

Genus **Pinnularia** Ehrenberg 1843

Section—*Nodosæ* A. Cl.

22. *Pinnularia acrosphæria* (Bréb.) W. Sm. f. *undulata* Cl.

(Fig. 15)

Hustedt, *Bacil.*, p. 330; Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p. 25, fig. 1022 *c*.

Valves linear, inflated in the middle with broadly rounded ends, 57–62 μ long and 10·5–11 μ broad. Raphe thin and straight with closely set and unilaterally bent central pores. Axial area very wide with irregularly disposed punctæ; central area not prominent. Striæ slightly radial in the middle 9–10 in 10 μ, and scarcely convergent at the ends.

23. *Pinnularia acrosphæria* (Bréb.) W. Sm. v. *minor* Cl.

(Fig. 16)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p. 25, fig. 1022 *d*.

Valves smaller than the type, 35–37 μ long and 8·8 μ broad with less dilated middle part and the ends. Striæ 12–13 in 10 μ, slightly radial in the middle or apparently parallel and scarcely convergent at the ends.

(*b*) *Sub-family* GOMPHOCYMBELLOIDEÆ

Genus **Amphora** Ehrenberg 1840

24. *Amphora veneta* (Kütz.) Hust.

Van Heurck, *Treat. Diat.*, p. 134, pl. 1, fig. 11; Hustedt, *Bacil.*, p. 345, fig. 631; Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—III, p. 96, fig. 682 *a–c*.

Frustules elliptical with rounded truncate ends in the girdle view, 10–12 μ broad. Valves convex on the dorsal and somewhat concave on the ventral side with curved obtuse ends, 17–22 μ long and 3–4·5 μ broad. Raphe thin and straight with central pores dorsally bent and terminal fissures ventrally directed. Axial area narrow. Striæ fine but distinctly punctate, 16–20 in 10 μ in the middle and 20–26 in 10 μ at the ends.

Genus **Cymbella** Agardh 1830

25. *Cymbella turgida* (Greg.) Cl.

Hustedt, *Bacil.*, p. 358, fig. 660; Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p, 123, fig. 1176 *a–d*; *Encyonema turgidum* (Greg.) Grun.—Van Heurck, *Treat. Diat.*, p. 149, pl. 1, fig. 45.

Valves convex on the dorsal and almost straight or slightly concave on the ventral side with a median inflation, ends acutely rounded, 40–54 μ long and 12–13 μ broad. Striæ distinctly lineate 8–9 in 10 μ, radial in the middle and convergent at the ends only on the ventral side.

26. *Cymbella ventricosa* Kütz. v. *genuina* Mayer

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p. 124, fig. 1177 *a–c*. *C. ventricosa* Kütz.—Hustedt, *Bacil.*, p. 359, fig. 661; *Encyonema ventricosum* Kütz.—Van Heurck, *Treat. Diat.*, p. 150, pl. 1, fig. 49.

Valves strongly convex on the dorsal and straight or slightly convex on the ventral side with acutely rounded ends, 29–35 μ long and 9–9·5 μ broad. Raphe thin and straight. Axial area narrow. Striæ 10–12μ in the middle and 12–16 in 10μ at the ends, radial, coarse, lineate and slightly convergent at the ends.

27. *Cymbella cymbiformis* (Ag. ?) Kütz. v. *unipuncta* A. Cl.
(Fig. 17)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p. 160, fig. 1246 *a–b*. *C. cymbiformis* Ehr.—Van Heurck, *Treat. Diat.*, p. 147, pl. 1, fig. 38; *C. cymbiformis* (Ag. ?, Kütz.) V.H.·—Hustedt, *Bacil.*, p. 362, fig. 672.

Valves sickle-shaped, asymmetrical, dorsal side convex, ventral side almost straight or concave and inflated in the middle, ends broadly rounded, 46–65 μ long and 11–13 μ broad. Raphe arcuate and thick with ventrally bent central pores and dorsally directed terminal fissures. Axial area fairly wide; central area slightly enlarged with an isolated punctum on the ventral side at the end of the central striæ. Striæ 8–10 in 10 μ, radial, strong and lineate.

28. *Cymbella cymbiformis* (Ag. ?) Kütz. v. *jimboi* (Pant.) A. Cl.
(Figs. 18–19)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p. 160, fig. 1246 *g*.

Valves sickle-shaped more inflated in the middle on the ventral side than the type with broadly rounded ends, 55–75 μ long and 12–14 μ broad. Central area with 2–3 coarse punctæ on the ventral side. Striæ 9–10 in 10 μ, radial and lineate.

29. *Cymbella cymbiformis* (Ag. ?) Kütz. v. *multipunctata* A. Cl.
(Fig. 20)

Cleve-Euler, A. *Diat. von Schwed. u. Finn.*—IV, p. 161, fig. 1246 *h, i*.

Valves sickle-shaped with convex dorsal and concave ventral side inflated in the middle, ends broadly rounded and truncate, 70–80 μ long and 11–13 μ broad. Central area slightly widened with 3–5 coarse punctæ on the ventral side. Striæ 7–8 in 10 μ, distinctly lineate-punctate and radial.

30. *Cymbella cymbiformis* (Ag. ?) Kütz. v. *nerei* (Pant.) A. Cl.
(Fig. 21)

Cleve-Euler, A. *Diat. von Schwed. u. Finn.*—IV, p. 161, fig. 1246 *k–l*.

Valves narrowly sickle-shaped than the type with strongly inflated ventral side in the middle, ends gradually narrowed and broadly

truncate rounded, 60–80 μ long and 11–13 μ broad. Striæ 8–9 in 10 μ radial and lineate.

Genus **Gomphonema** Agardh 1824

31. *Gomphonema subapicatum* Fritsch and Rich

(Fig. 22)

Fritsch, F. E. and Rich, F., *Diat. from Griqueland West.*, p. 108, fig. 6 *a–b*; Abdul-Majeed, M., *Bacil.*, p. 31, pl. 3, fig. 4.

Valves lanceolate-clavate, dilated in the middle, apex wedge-shaped, somewhat constricted and subapiculate, base narrowly rounded, 48–99 μ long and 12–15·6 μ broad. Raphe thin and straight. Axial area narrow, linear; central area unilateral, fairly large with an isolated stigma on the opposite side. Striæ 9–12 in 10 μ, radial, distinctly punctate and somewhat widely set in the middle.

32. *Gomphonema augur* Ehr. v. *genuinum* Mayer

(Fig. 23)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p. 176, fig. 1265 *a–b*. *G. augur* Ehr.—Van Heurck, *Treat. Diat.*, p. 271, pl. 7, fig. 301; Hustedt, *Bacil.*, p. 372, fig. 688.

Valves broadly ovate-clavate with apiculate rounded apex and strongly attenuated base, 26–32 μ long and 8·5 μ broad. Raphe thin and straight. Axial area narrow; central area unilateral, large with an isolated stigma on the opposite side. Striæ 12–16 in 10 μ, slightly radial, indistinctly punctate and closely set at the ends.

33. *Gomphonema parvulum* (Kütz.) V. H. v. *genuinum* Mayer.

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p. 177, fig. 1269 *a–c*. *G. parvulum* (Kütz.) Grun.—Van Heurck, *Treat. Diat.*, p. 272, pl. 7, fig. 306; Hustedt, *Bacil.*, p. 372, fig. 713 *a*.

Valves broadly lanceolate-clavate with constricted, shortly rostrate ends, 18–24 μ long and 6–6·5 μ broad. Raphe thin and straight. Axial area very narrow; central area small unilateral with an isolated stigma on the opposite side. Striæ 14–16 in 10 μ, radial and indistinctly punctate.

34. *Gomphonema parvulum* (Kütz.) V. H. v. *subellipticum* Cl.

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p. 178, fig. 1269 *h*. *G. parvulum* (Kütz.) Grun. v. *subelliptica* Cl.—Hustedt, *Bacil.*, p. 373, fig. 713 *b*.

Frustules small. Valves clavate-elliptical with scarcely constricted produced ends, 16–18 μ long and 6–6 μ broad. Striæ 13–15 in 10 μ, radial and indistinctly punctate.

35. *Gomphonema montanum* Schum. v. *acuminatum* Mayer

(Fig. 24)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p. 183, fig. 1276 *e–k*.

Valves broadly clavate-lanceolate with wedge-shaped, slightly constricted apiculate apex and graudally narrowed towards the acutely rounded base, 35·5–40 μ long and 12 μ broad. Raphe thin and straight. Axial area narrow, linear; central area unilateral with an isolated stigma on the opposite side. Striæ 10–11 in 10 μ, radial and distinctly punctate.

36. *Gomphonema dharwarensis* sp. nov.

(Figs. 25–27)

Frustula angusta-cuneati in aspectu zonali. Valvæ lineari-clavatæ, apex sæpsi atque late cuneatis; basi gradatim fastigatæ atque acuti-rotundati, margines aliquantum undulatis. Raphe crassa, unilateraliter inclinatis atque comma similibus in nodulus medio, fissuris terminalibus distincte. Area axialis lata; area centralis unilateraliter ornata puncto uno at latus. Stiæ fortes, tenuiter radiales, lineatæ atque proxime positæ in utroque apice. Frustula 66–75 μ longa, 8–9 μ lata, striæ 6–8 in medio atque 8–12 in 10 μ in utroque apice.

Habitat.—Aquæ dulcis. Lacu in horto.

Frustules narrowly wedge-shaped in the girdle view. Valves linear-clavate, apex septate and broadly cuneate, base gradually narrowed and acutely rounded, margins somewhat undulated. Raphe thick with unilaterally bent, comma-shaped ends in the central nodule, terminal fissures distinct. Axial area wide; central area unilateral with an isolated stigma on one side. Striæ strong, slightly radial, lineate and closely set at the ends. Frustules 66–75 μ long, 8–9 μ broad with 6–8 striæ in the middle and 8–12 in 10 μ at the ends.

Habitat.—Fresh-water. Garden reservoirs.

This form resembles *G. intricatum* Kütz. and its varieties (Hustedt, *Bacil.*, pp. 187–89, figs. 697–99; Cleve-Euler, *Diat. von Schwed. u. Finn.*—IV, pp. 187–89, fig. 1283), in the outline, in number and arrangement of the striæ. However, it markedly differs from them in having cuneate septate apex and coarsely lineate striæ instead of clearly punctate ones. Moreover, the raphe ends in the central nodule are clearly comma-shaped and the central area comparatively smaller than in *G. intricatum* Kütz. It also differs from *G. dubravicense* Pant. (Cleve-Euler, *op. cit.*, p. 190, fig. 1826 *a–b*) in having no other punctæ in the mid-axial area than an isolated stigma and comma-shaped ends of the raphe in the central nodule. It also does not agree with any other forms with regards to lineate striæ and comma-shaped endings of raphe in the central nodule. It is, therefore, regarded as a new species.

37. *Gomphonema olivaceum* (Lyng.) Kütz. v. *balticum* Cl.

(Fig. 28)

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—IV, p. 192, fig. 1291 *a–d*. *G. olivaceum* (Lyng.) Kütz.—Hustedt, *Bacil.*, p. 378, fig. 719 *a*.

Valves ovate-clavate with broadly rounded apex and attenuated base, 25–30 μ long and 5·5–6 μ broad. Raphe thin and straight.

Axial area narrow; central area large unilateral without an isolated stigma. Striæ 7-12 in 10 μ, radial and curved, indistinctly punctate and closely set at the ends.

2. *Family* *EPITHEMIACEÆ*
(*a*) *Sub-family* EPITHEMIOIDEÆ
Genus **Epithemia** Brébisson 1838

38. *Epithemia sorex* Kütz. v. *genuina* A. Cl.

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—V, p. 41, fig. 1412 *a–b*. *E. sorex* Kütz.—Van Heurck, *Treat. Diat.*, p. 295, pl. 9, fig. 351; Hustedt, *Bacil.*, p. 388, fig. 736; Iyengar and Subrahmanyan, *Fossil Diat.*, p. 233, fig. 17.

Frustules epiphytic on aquatic plants, rectangular and somewhat curved in the girdle view. Valves strongly convex on the dorsal—and slightly concave on the ventral side with constricted, rounded capitate recurved ends, 31–37 μ long and 8·4–9·6 μ broad. Raphe in the raphe canal strongly arcuate with central pores almost reaching the dorsal side. Costæ 5–7 in 10 μ, strong, radial and alternating with 2–3 rows of aerioles, rows of aerioles 12–15 in 10 μ.

(*b*) *Sub-family* RHOPALODIOIDEÆ
Genus **Rhopalodia** O. Müll. 1895

39. *Rhopalodia gibba* (Ehr.) O. Müll. v. *genuina* Grun.

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—V, p. 44, fig. 1416 *a, e*. *R. gibba* (Ehr.) O. Müll.—Hustedt, *Bacil.*, p. 390, fig. 740; *Epithemia gibba* Kütz.—Van Heurck, *Treat. Diat.*, p. 296, pl. 9, fig. 352 *a*.

Frustules epiphytic on aquatic plants, broadly linear in the girdle view with notched inflation in the middle and broadly truncate ends, 20–25 μ broad. Valves gibbous and notched on the mid-dorsal side, ventral side straight or slightly depressed towards the acutely rounded curved ends, 8–10 μ broad and 80–90 μ long. Costæ 5–7 in 10 μ, strong, parallel in the middle and becoming strongly radial at the ends, alternating with 2–3 rows of aerioles, rows of aerioles 10–15 in 10 μ, fine but distinct.

40. *Rhopalodia gibba* (Ehr.) O. Müll. v. *ventricosa* (Kütz.) Grun.

Hustedt, *Bacil.*, p. 391, fig. 741; Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—V, p. 44, fig. 1416 *c–d*; *R. ventricosa* (Kütz.) O. Müll.—Tiffany and Britton, *Alg. Illinois*, p. 282, pl. 75, fig. 885; *Epithemia gibba* Kütz. v. *ventricosa* Kütz.—Van Heurck, *Treat. Diat.*, p. 296, pl. 9, fig. 354.

Frustules smaller than the type and more gibbous in the middle with truncate broadly rounded ends in the girdle view, 30–38 μ long and 18–19 μ broad. Costæ strongly radial towards the ends, 6–7 in 10 μ, alternating with 2–3 rows of aerioles, rows of aerioles 10–14 in 10 μ.

3. *Family* *NITZSCHIACEÆ*
(*a*) *Sub-family* NITZSCHIOIDEÆ
Genus **Nitzschia** Hassall 1845

Section—**Lineares** (Grunow) Hustedt and others

41. *Nitzschia sublinearis* Hustedt

Hustedt, *Bacil.*, p. 411, fig. 786; Cleve-Euler, A., *Diat. von Schwed. u. Finn.*,—V, p. 80, fig. 1481.

Valves elongated, slightly backwardly bent with long wedge-shaped, constricted somewhat capitate ends, 65–88 μ long and 5–6 μ broad. Keel excentric without any notch in the middle, keel punctæ 8–12 in 10 μ, distinct. Striæ over 30 in 10 μ, very fine.

Section—**Lanceolatæ** Grunow

42. *Nitzschia amphibia* Grun. v. *genuina* Mayer

Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—V, p. 86, fig. 1496 *a–c*. *N. amphibia* Grun.—Van Heurck, *Treat. Diat.*, p. 403, pl. 17, fig. 563; Hustedt, *Bacil.*, p. 414, fig. 793.

Valves linear to linear-lanceolate with somewhat wedge-shaped constricted ends, 29–35 μ long and 4·4–5 μ broad. Keel excentric with large keel punctæ 7–8 in 10 μ. Striæ 16–18 in 10 μ, distinctly punctate.

43. *Nitzschia amphibia* Grun. v. *acutiuscula* Grun.

(Fig. 29)

Hustedt, *Bacil.*, p. 414,; Cleve-Euler, A., *Diat. von Schwed. u. Finn.* —V, p. 86, fig. 1496 *f–i*.

Valves lanceolate with scarcely constricted, acutely rounded ends, 14–22 μ long and 5–5·6 μ broad. Keel excentric with large keel punctæ 7–8 in 10 μ. Striæ 15–18 in 10 μ, distinctly punctate.

Section—**Obtusæ** Grun.

44. *Nitzschia obtusa* W. Sm. v. *scalpelliformis* Grun.

Van Heurck, *Treat. Diat.*, ρ. 397, pl. 16, fig. 538; Hustedt, *Bacil.*, p. 422, fig. 817 *b*; Venkataraman, *S. I. Diat.*, ρ. 355, figs. 142, 147; Cleve-Euler, A., *Diat. von Schwed. u. Finn.*—V, p. 78, fig. 1476 *f, h*.

Frustules elongated and sigmoid in the girdle view, linear. Valves linear, slightly sigmoid with obliquely wedge-shaped ends, 87–100 μ long and 8–9 μ broad. Keel excentric with large rounded keel punctæ 6–8 in 10 μ, keel notched in the middle. Striæ very fine about 30 in 10 μ.

SUMMARY

For the first time the fresh-water Diatomaceæ of Dharwar has been investigated of which an illustrated account is given.

In the introduction topography of the place is given and mention has been made of features of the material from different places of collection.

In all 44 forms have been described and illustrations are given only of those which do not appear in the Indian literature. Of these forms, 18 are new records for India, one is a new species and one a new variety.

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SOME SLIME-MOULDS FROM SOUTHERN INDIA—V

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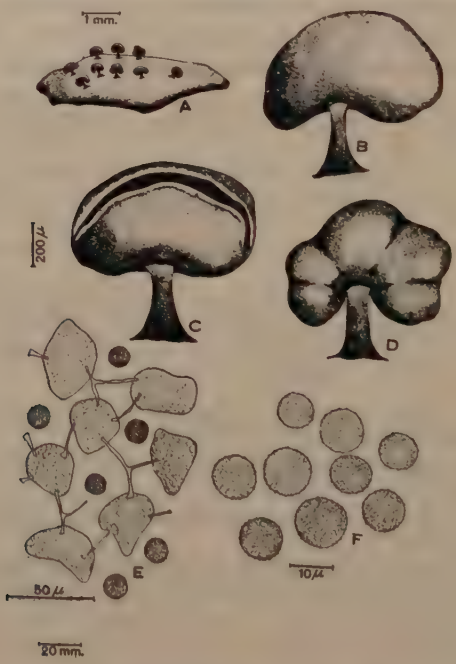
21. *Physarum compressum* Alb. and Schw., in *Consp. Fung.*, 1805, p. 97; Saccardo, *Syll. Fung.*, **7**: 1888, p. 337; Petch, *Ann. R. bot. Gdns.*, Peradeniya, **4**: 1909, pp. 333–34; Macbride, *The North American Slime-Moulds*, 1922, p. 80; Lister, *A Monograph of the Mycetozoa*, 3 rd ed., 1925, pp. 49–50.

Plasmodium not observed. Sporangia typically scattered, measuring 0·75–1·5 mm. in total height, compressed, reniform, smooth or lobed, often umbilicate below, typically stipitate, rarely plasmodiocarpous or confluent sporangia were observed in some collections. Sporangial wall white or ashen-grey in colour, heavily impregnated with minute granules of lime, dehiscing along the apical edge by a

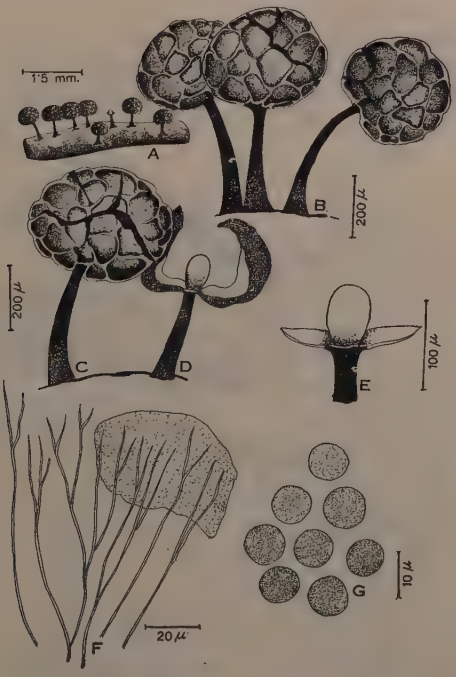


Text-Fig. 1. *Physarum compressum* Alb. and Schw. A, Sporangia on the bark of *Wrightia tinctoria*; B, A reniform compressed sporangium; C, Showing the apical cleft-like dehiscence of a reniform sporangium; D, A lobed sporangium; E, Capillitial threads and the lime knots; F, Spores.

cleft so that a dehisced sporangium has two widely gaping halves of the peridium. Stalk terete in cross-section, stout, erect, dark brown to almost black, enclosing refuse matter, with a well-developed hypothallus. Capillitium well developed, typically physaroid, forming a close reticulum consisting of hyaline threads anastomosing with round, subangular, white lime knots, highly variable in size. Spore mass deep fuscous brown, individually brownish purple in colour, distinctly echinulate, spherical to subglobose, measuring on average 11·4 μ, range 9·6–12·8 μ, mostly 12·0 μ.

On the bark of *Wrightia tinctoria* R. Br., Agri-Horticultural Gardens, Madras, 10–9–1954 (Herb. M.U.B.L. No. 1236); on the bark of *Morinda tinctoria* Roxb., University Campus, Marina, Madras, 14–9–1954 (Herb. M.U.B.L. No. 1237). All collections were made by V. Agnihothrudu.

22. *Diderma rugosum* (Rex.) Macbride, in *The North American Slime-Moulds*, 1899, p. 105; Petch, *Ann. R. bot. Gdns., Peradeniya*, **4**: 1909, p. 345 as *Chondrioderma rugosum* Rex.; as *Diderma rugosum* (Rex.) Macbride, *The North American Slime-Moulds*, 1922, p. 144; Lister, *A Monograph of the Mycetozoa*, 3rd ed., 1925, p. 99.

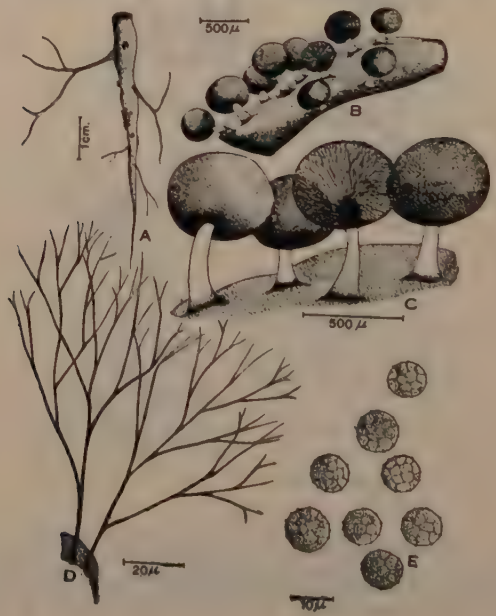


TEXT-FIG. 2. *Diderma rugosum* (Rex.) Macbride. A, Sporangia on a twig; B, Sporangia showing the polygonal areolæ and the method of dehiscence; C, Irregularly dehisced sporangium; D, Dehisced sporangium with the columella; E, Columella; F, Capillitium and a part of the peridium; G, spores.

Plasmodium not observed. Sporangia gregarious, scattered, measuring 0·6–1 mm. in total height, typically stipitate. Sporangium proper 0·4–0·7 mm. in diameter, globose, to subhemispherical, white or ashen-grey and pale brown at the base. Peridium distinctly rugose, divided into 20–30 polygonal shallow facets. These reticulate ridges or wrinkles pre-figure the line of dehiscence. In some instances the dehiscence of the sporangia was not along the ridges of the æreolæ. Sporangial wall single, thin, papery, densely impregnated with lime granules. Stalk terete, 0·2–0·8 mm. in height, subulate, furrowed, deep brown to black in colour, hypothallus none. After the spore dispersal the columella is seen distinctly with the remnants of the peridial wall. Columella clavate, reaching almost half the height of the sporangium, rough chalky to pale yellowish white in colour. Capillitium well developed, consisting of slender purplish threads sparingly furcate and anastomosing, the lower ends attached to the columella, the upper ends to the peridium. Spores deep brown in mass, pale purplish brown in transmitted light, spherical to subglobose, minutely warted, measuring on average 9·8 μ, range 8·0–11·2 μ mostly 10·4 μ in diameter.

Only one collection was made on decomposing leaves of *Cocos nucifera* L. and some unidentified decaying twigs, Agri-Horticultural Gardens, Madras, 10–10–1954, coll. V. Agnihothrudu (Herb. M.U.B.L. No. 1238).

23. *Diachea subsessilis* Peck. in *Rep. N.Y. Mus. Nat. Hist.*, 1879, p. 31; Petch, *Ann. R. bot. Gdns., Peradeniya*, **4:** 1909, p. 347; Macbride, *The North American Slime-Moulds*, 1922, p. 187; Lister, *A Monograph of the Mycetozoa*, 3rd ed., 1925, p. 104.



TEXT-FIG. 3. *Diachæa subsessilis* Peck. A, Sporangia on an incubated pigeon-pea root; B and C, Sporangia showing the columella and the radiating capillitium; D, Capillitial threads; E, Spores.

Plasmodium not observed. Sporangia gregarious, globose to subhemispherical, up to 0·6 mm. in diameter, dull iridescent, bluish green in colour, short stipitate. Peridial wall thin, membranous, evanescent, exposing the spore mass entangled in the capillitial threads. Stipe stout, cylindrical or conical when extremely reduced with an incipiently developed hypothallus, white to pale brown in colour, impregnated with lime granules, measuring 0·1–0·5 mm. Columella distinct, persistent, white, capillitium well developed radiating from the columella, consisting of profusely branched and anastomosing pale purplish brown threads, deeper in hue and stouter at the collumellar end and paler at the peridial extremity. Spore mass deep purple grey in colour, individually violaceo-fuscous, ornamented with closely reticulated delicate raised bands, measuring on average 8·8 μ, range 6·8–9·6 μ, mostly 9·2 μ in diameter. This myxomycete appeared only in one instance on incubated roots of pigeon-pea plants grown in the University Botany Field Research Laboratory, Madras, Coll. V. Agnihothrudu (Herb. M.U.B.L. No. 1251).

24. *Lamproderma scintillans* (Berk. and Br.) Morgan in *J. Cinc. Soc. Nat. Hist.*, **16**: 1894, p. 131; as *Enerthenema muscorum* Lev., in *Ann. Sci. Nat. series*, **4**: **20**: 1863, p. 289; as *Lamproderma scintillans* (Berk. and Br.) Morgan, Macbride, in *The North American Slime-Moulds*, 1922, pp. 195–96; Schinz, *Rabenhorst's Kryptogamen Flora*, Abt., **10**: 1920, p. 261; Lister, *A Monograph of the Mycetozoa*, 3rd ed., 1925, 153–54; Brühl and Sen Gupta, *J. Dep. Sci. Calcutta Univ.*, **8**: 1927, p. 118; Lodhi, *Publ. Univ. Punjab*, 1934, p. 16.

Plasmodium not observed. Sporangia gregarious or scattered, globose, total height being 0·75–1·5 mm., sporangia proper 0·2–0·6 mm. in diameter, brilliantly metallic blue in colour. Peridium thin, delicate, fugacious, falling off in large flakes exposing the spore mass. Stipe long, rigid, setaceous, gradually tapering towards the sporangial end, deep brown to almost black in colour, arising from a small circular hypothallus, measuring up to 1 mm. in height. Columella distinct, appearing as a prolongation of the apex of the stipe, cylindrical, truncate, scarcely attaining half the height of the sporangium. Capillitium composed of rigid threads radiately arranged on the vertex of the columella, dichotomously branched and anastomosing, purple brown in colour, paler at the base, darker at the extremities. The threads appear at first sight simple but are really furcate and anastomose. The threads connecting the columella with the rather persistent base of the sporangial wall are slender and almost hyaline. Spores violaceous brown, distinctly warted, spherical, measuring on average 7·3 μ, range 6·0–8·0 μ, mostly 7·6 μ in diameter.

On dead twigs of *Pithecolobium dulce* Benth., Ayanavaram, Madras, 13-9-1954 (Herb. M.U.B.L. No. 1239); on decomposing twigs of

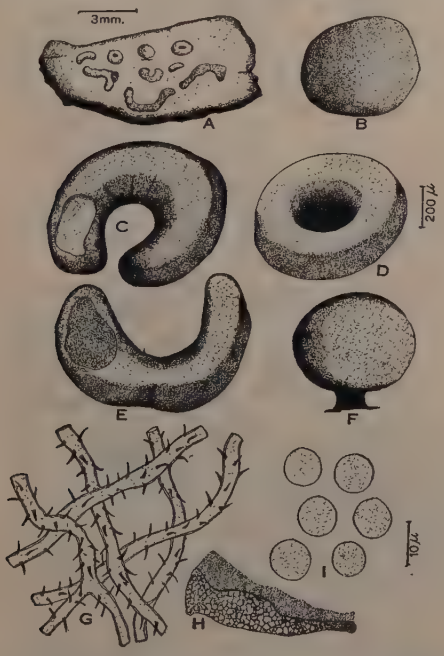
TEXT-FIG. 4. *Lamproderma scintillans* (Berk. and Br.) Morgan. A, Sporangia on a twig of *Pithecolobium dulce*; B, Sporangia showing the long stipe and the persistent capillitium; C, A dehisced sporangium showing the columella, the radiating capillitial threads, and the persistent base of the sporangial wall; D, Capillitial threads; E, Spores.

Feronia elephantum Corr., Perambur, Madras, 16–9–1954 (Herb. M.U.B.L. No. 1240); on dead twigs of *Tamarindus indicus* L., Soundarya Nursery, Madras, 18–9–1954 (Herb. M.U.B.L. No. 1241); on decomposing unidentified twigs, Queen Mary's College Campus, Marina, Madras, 26–9–1954 (Herb. M.U.B.L. No. 1242); on decaying leaves of *Bignonia unguis-cati* L., Agri-Horticultural Gardens, Madras, 20–10–1954 (Herb. M.U.B.L. No. 1243). All collections were made by V. Agnihothrudu.

25. *Perichæna chrysosperma* Lister in Mycetozoa, 1894, p. 196; Petch, *Ann. R. bot. Gdns., Peradeniya*, **4**: 1909, p. 368, as *Ophiotheca chrysosperma* Currey; Macbride, *The North American Slime-Moulds*, 1922, p. 241; as *Perichæna variabilis* var. *pedata* Lister in *J. Bot.*, **42**: 1904, p. 139; as *Perichæna corticalis* var. *affinis* Lister, in *Mycetozoa*, 1911, p. 251; as *P. chrysosperma* Lister in *A Monograph of the Mycetozoa*, 1925, pp. 243–44; Lodhi, *Publ. Univ. Punjab*, 1934, p. 25.

Plasmodium not observed. Sporangia subgregarious, sessile or stalked, simple or plasmodiocarpous. Individual sporangia measuring

0·4–1·0 mm. in diameter, spherical, globose or subhemispherical. Plasmodiocarps short, up to 4 mm. long, curved, horse-shoe-shaped or forming perfect rings, reddish brown to blackish brown in colour. Peridium dehiscing irregularly or falling apart in flakes exposing the spore mass. Peridium composed of two layers, an outer thicker and darker layer impregnated densely with brown granular matter and an inner translucent pale yellow submembranous layer which is rather faintly papillose. Stipe when present short, cylindrical, stout, deep brownish black enclosing refuse matter, measuring up to 0·4 mm. in height. Spore mass bright yellow in colour enclosed by profuse capillitial threads which measure up to 3·6 μ in diameter, constricted at irregular intervals and studded with prominent, slightly recurved spines measuring up to 3·0 μ in length. Spores typically citron yellow *en masse*, individually almost hyaline, minutely warted, measuring on average 9·4 μ, range 8·8–10·4 μ, mostly 9·6 μ in diameter.

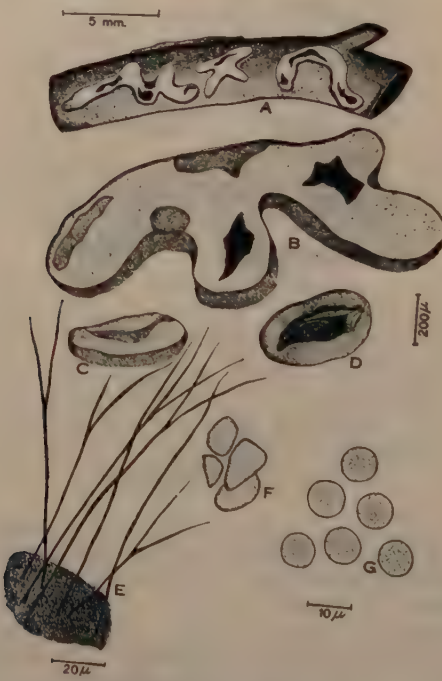


TEXT-FIG. 5. *Perichæna chrysosperma* Lister. A, Sporangia on the bark of *Wrightia tinctoria*; B, C, D and E, Sessile sporangia of different shapes; F, A stipitate sporangium; G, Capillitial threads with spines; H, Showing the double-layered nature of the peridium; I, Spores.

On bark of *Pithecolobium saman* Benth., Mylapore, Madras, 14–10–1954 (Herb. M.U.B.L. No. 1244); on bark of *Wrightia tinctoria* R. Br., Agri-Horticultural Gardens, Madras, 18–10–1954 (Herb. M.U.B.L. No. 1245); on bark of *Tamarindus indicus* L., Ayanavaram, Madras, 18–10–1954 (Herb. M.U.B.L. No. 1246). All collections were made by V. Agnihothrudu.

26. *Diderma effusum* (Schw.) Morgan, in *J. Cinc. Soc. Nat. Hist.*, **16** : 1894, p. 155; as *Chondrioderma reticulatum* Rost.; Lister, in *Mycetozoa*, 1894, p. 79; Petch, in *Ann. R. bot. Gdns., Peradeniya*, **4** : 1909, p. 344; as *Diderma reticulatum* Morg., Macbride, *The North American Slime-Moulds*, 1899, p. 95; as *Diderma effusum* (Schw.) Morgan, Macbride, *The North American Slime-Moulds*, 1922, pp. 130–31; Lister, *A Monograph of the Mycetozoa*, 1925, pp. 85–86; Brühl and Sen Gupta, *J. Dep. Sci. Calcutta Univ.*, **8** : 1927, p. 114; Lodhi, *Publ. Univ. Punjab*, 1934, p. 11.

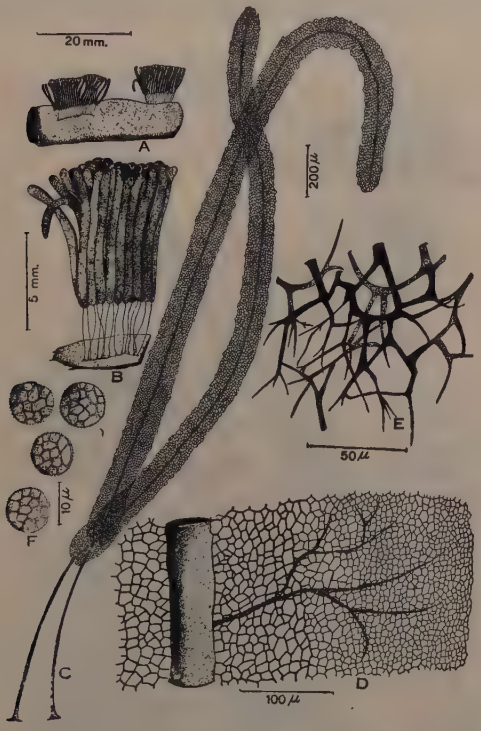
Plasmodium not observed. Fructifications plasmodiocarpous. Sporangia gregarious or crowded, creeping, applanate and generally effuse, milky white or pale dirty brown up to 2 cm. long and 2 mm. broad. Peridium double-layered, an outer fragile fugacious crust of calcareous granules which separates from an inner thin membranous colourless layer. Columella present, short, globose, pulvinate or depressed, dirty brown or pale pinkish enclosing large lime granules. Capillitium dense, consisting of short thin threads sparsely branched. Spores violet brown, almost smooth, measuring on average 8·3 μ, range 6·4–10·4 μ, mostly 8·9 μ.



TEXT-FIG. 6. *Diderma effusum* (Schw.) Morgan. A, Plasmodiocarps on decaying twigs of *Croton sparsiflorus*; B–D, Plasmodiocarps showing the double nature of the peridium; E, Capillitium attached to the peridium; F, Lime granules; G, Spores.

On decaying leaves of *Cocos nucifera* L., Agri-Horticultural Gardens, Madras, 13–7–1955 (Herb. M.U.B.L. No. 1536); on decomposing twigs of *Croton sparsiflorus* Morung, Mylapore, Madras, 18–8–1955 (Herb. M.U.B.L. No. 1537); on the mid-rib of an unidentified decaying leaf, University Botany Laboratory Campus, Madras, 18–10–1955 (Herb. M.U.B.L. No. 1538); on decaying leaves of *Terminalia paniculata* Roth., Guntur (Andhra State), 22–1–1956, (Herb. M.U.B.L. No. 1539). All collections were made by V. Agnihothrudu.

27. *Stemonites fusca* (Roth.) Rostafinski in *Sluzowce* (*Mycetozoa*) *Monografia*, Parys, 1875, p. 193; Macbride, *The North American Slime-Moulds*, 1922, p. 160; Lister, *A Monograph of the Mycetozoa*, 3rd ed., 1925, pp. 132–34.



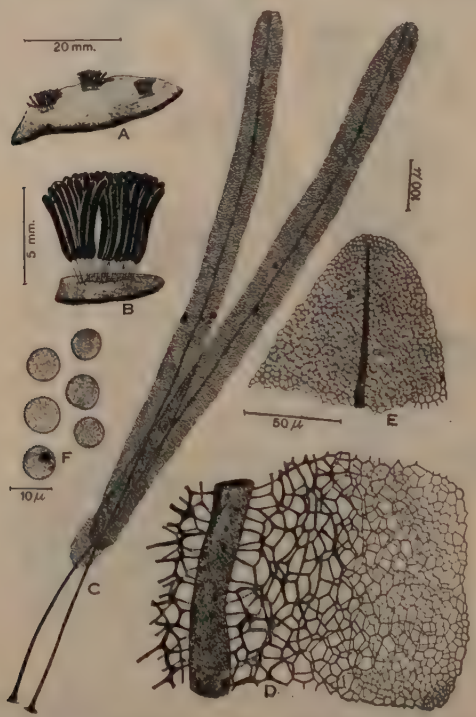
TEXT-FIG. 7. *Stemonites fusca* (Roth.) Rost. A and B, Sporangial aggregates; C and D, Sporangia with columella and capillitial reticulum; E, Capillitium; F, Spores.

Plasmodium not observed. Sporangia in large aggregations, measuring up to 2 cm. in height. Sporangia cylindrical obtuse, stipitate, deep purple. Stipe black, setaceous, shining, up to 5 mm. long with distinct brown membranous hypothallus which is common to all sporangia. Columella reaching to the apex of the sporangium. Capillitium consisting of dark brownish purple threads springing from all parts of the columella, profusely branched and anastomosing to form

a lax reticulum proximal to the columella, the ultimate ramifications of the capillitium being slender, subhyaline, forming a close meshed surface net. Spores deep purple in mass, reddish violet in transmitted light, with continuous raised bands forming a reticulum, measuring on average 9·8 μ, range 8·4–11·8 μ mostly, 10·4 μ in diameter.

On stumps and twigs of *Casuarina equisetifolia* Forst., Professor T. S. Sadasivan's farm, Guindy, Madras, 8–9–1954, Coll. V. Agnihothrudu, Miss P. Shanta and S. Suryanarayanan (Herb. M.U.B.L. No. 1540); on decaying wood, Ayanavaram, Madras, 7–8–1955, Coll. V. Agnihothrudu (Herb. M.U.B.L. No. 1541).

28. *Stemonites herbatica* Peck in *Rep. N.Y. Museum*, **26:** 1874, p. 75; Macbride, *The North American Slime-Moulds*, 1922, p. 171; Lister, *A Monograph of the Mycetozoa*, 3rd ed., 1925, p. 137.



TEXT-FIG. 3. *Stemonites herbatica* Peck. A and B, A group of sporangia on decaying leaf-sheath of *Musa paradisiaca* L.; C, D and E, Showing columella and capillitial reticulum; F, Spores.

Plasmodium not observed. Sporangia clustered in scattered aggregates, cylindric, obtuse, brownish red or dilute ferruginous up to 10 mm. high, stipitate, Stipe deep fuscous or black, 1–3 mm. long arising from a membranous but a distinct hypothallus. Columella

distinct, reaching almost the tip of the sporangium. Capillitium consisting of dark brown threads forming a lax net work with wide expanded nodes uniting at the surface into a dense mesh of delicate colourless strands. Spore mass ferruginous, spores globose, minutely spinulose, measuring on average 6·8 μ, range 5·0–8·4 μ, mostly 8·0 μ in diameter.

On the leaf sheath of *Musa paradisiaca* L., Chingleput, 18–7–1955, Coll. Miss K. Bhuvaneswari (Herb. M.U.B.L. No. 1542).

29. *Physarum melleum* (Berk. and Br.) Massee in *A Monograph of the Myxogastres*, London, 1892, p. 278; as *Didymium melleum* Berk. and Br. in *J. Linn. Soc.*, **14**: 1873, p. 83; as *Physarum melleum* (Berk. and Br.) Massee, Macbride, *The North American Slime-Moulds*, 1922, pp. 65–66.

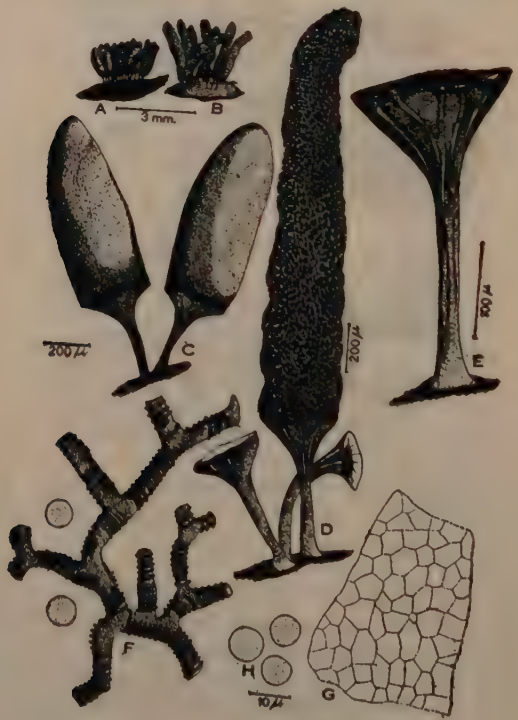
TEXT-FIG. 9. *Physarum melleum* (Berk. and Br.) Massee. A–C, Sporangia on decaying cocoanut leaves. D and E, Sporangia from collection Herb. M.U.B.L. No. 1545; F, Capillitium; G, Spores.

Plasmodium not observed. Sporangia scattered, measuring up to 1 mm. in height, globose or subglobose, slightly flattened below in some, yellow or honey-coloured measuring up to 600 μ in diameter. Stipe stout, short and wrinkled or long and smooth measuring up to 800 μ long, white or slightly brownish with an incipient hypothallus. Sporangial wall, thin membranous, smooth or wrinkled, yellowish with deposits of lime granules which are minute and citron yellow in

colour. The peridium falls off in flakes exposing the spore mass. Peridium persistent at the base. Columella short, small but distinct, conical or subspherical. Capillitium abundant, consisting of dense reticulum of irregularly branched hyaline threads, often expanded in the axils with pale yellow to sulphur yellow angular lime knots of various sizes and shapes. Spores violet, deep brown to almost black in mass, spherical or subglobose, almost smooth, measuring on average 8·5 μ, range 6·4–11·2 μ, mostly 9·6 μ in diameter.

This species was collected from three localities, in all instances on decaying leaves of *Cocos nucifera* L., Agri-Horticultural Gardens, Madras, 14–9–1955 (Herb. M.U.B.L. No. 1543); Tindivanam (Madras State), 18–10–1955, Coll. V. Agnihothrudu, Miss P. Shanta and S. Suryanarayanan (Herb. M.U.B.L. No. 1544); Guntur (Andhra State), 22–1–1956 (Coll. V. Agnihothrudu (Herb. M.U.B.L. No. 1545).

30. *Arcyria denudata* (Linn.) Wettstein in *Verusch. Zool.-Bot. Ges.*, Wien, 1855, p. 585; as *Arcyria punica* Lister, *Mycetozoa*, 1884, p. 188; as *Arcyria denudata* (Linn.) Wett., Macbride in *The North American Slime-Moulds*, 1922, pp. 253–54; Lister, *A Monograph of the Mycetozoa*, 3rd ed., 1925, pp. 235–36; Brühl and Sen Gupta, *J. Dep. Sci. Calcutta Univ.*, **8**: 1927, p. 121.



TEXT-FIG. 10. *Arcyria denudata* (Linn.) Wett. A and B, Undehisced and dehisced sporangia; C, Undehisced sporangia with evanescent peridium; D, Sporangia with capillitial reticulum; E, Calyculus; F, Capillitium; G, A fragment of sporangial wall; H, Spores.

Plasmodium not observed. Sporangia gregarious, measuring up to 4 mm. in height, stipitate, ovoid to subcylindrical, broader at the base tapering at the apex, brownish red in colour, measuring 0·5–2·2 mm. in height and 0·5–1·2 mm. broad, first red or crimson later becoming reddish brown or dirty brown in colour. Stalk terete, up to 1 mm. long and 0·2 mm. thick, furrowed, pale red, or deep reddish brown, filled with spore-like cells, with a well developed hypothallus. Calyculus well formed, membranous, plaited, smooth, wide, shallow. Capillitium centrally attached, consisting of dense reticulate threads brick red when fresh, fading with exposure. Capillitial threads terete up to 6·4 μ in diameter, ornamented with prominent cogs, half rings in lax spirals. Spores bright red in mass, pale red in transmitted light, globose to subglobose, smooth, measuring on average 7·3 μ, range 5·6–8·8 μ mostly 8·0 μ in diameter. On decaying stumps of *Cocos nucifera* L., Mylapore, Madras, 18–8–1955, Coll. V. Agnihothrudu (Herb. M.U.B.L. No. 1546); on stumps of *Phœnix* sp. Professor T. S. Sadasivan's farm, Guindy, Madras, 19–10–1955, Coll. V. Agnihothrudu, Miss P. Shanta and S. Suryanarayanan (Herb. M.U.B.L. No. 1547); on *Borassus flabellifer* L., Guntur (Andhra State), 22–1–1956 (Herb. M.U.B.L. No. 1548).

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STUDIES IN THE MELIACEÆ

I. Development of the Embryo in *Azadirachta indica* A. Juss.

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(Received for publication on March 13, 1956)

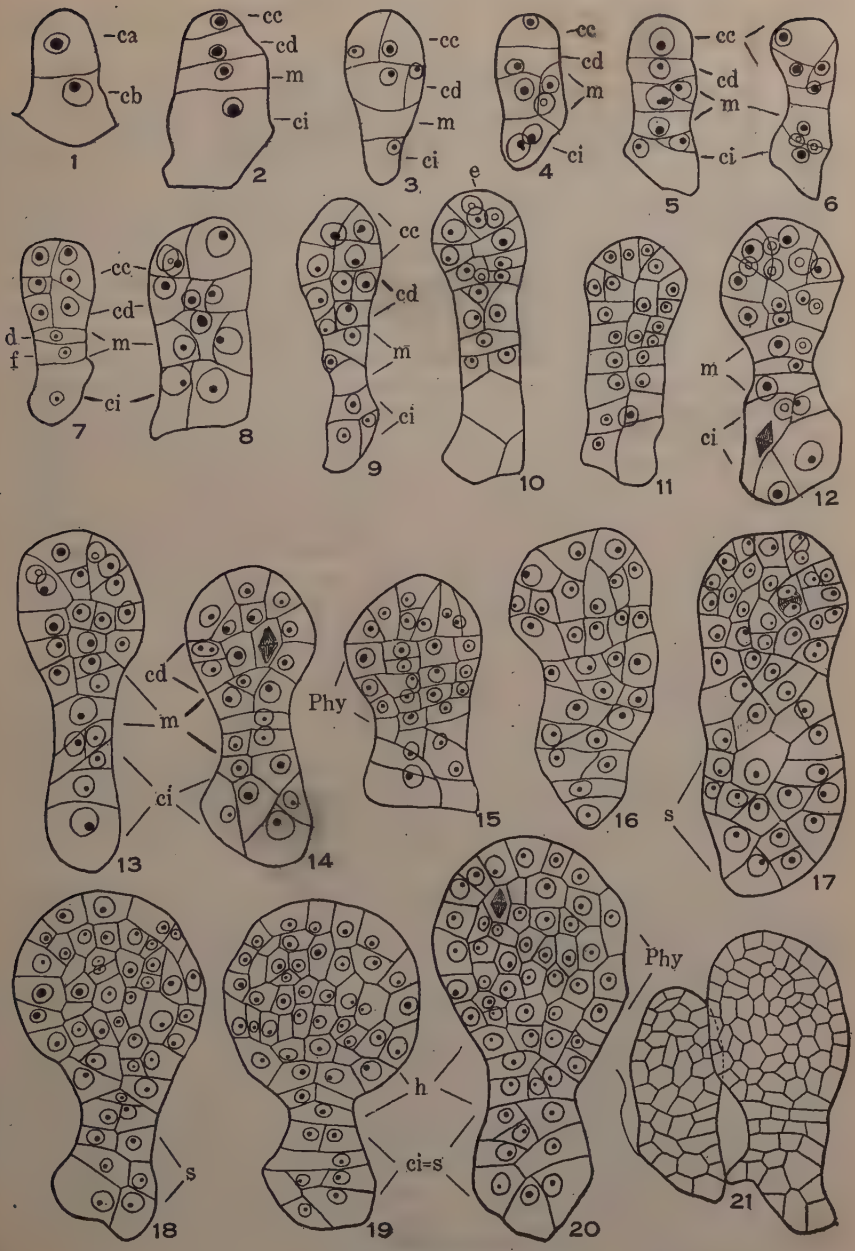
There has been, so far, no detailed account of the embryogeny of any member of the Meliaceæ. Johansen (1950) has stated that the information available on the Meliaceæ is insufficient to permit any conclusions. Wiger (1935) who investigated a number of species of the Meliaceæ figured a few embryos of *Dysoxylum alliaceum* and *Melia azaderach*. These are many celled embryos and in regard to earlier stages, he writes that he did not observe the development following the two-celled condition. The present study was, therefore, undertaken with a view to understand the embryogeny of some representatives of this important tropical family. A detailed account of the development of the embryo in *Azadirachta indica* is given in this paper.

Material and Methods

Azadirachta indica is a well-known tree of the tropics which is cultivated extensively as a shade plant and whose leaves are used in indigenous medicine. The plants bear flowers in great profusion during the months, February to July. The material for study was collected from plants growing in a private garden in Bangalore and fixed in formalin-acetic-alcohol. Preparations for microscopic examination were made according to customary schedule.

Observations

The fertilized egg divides by a transverse wall resulting in the two superposed cells, the apical and the basal cells (*ca* and *cb* in Fig. 1). A linear tetrad of the C_2 category is formed following transverse division in each of the cells, *ca* and *cb* (Fig. 2). The terminal cell, *cc* undergoes an oblique division and a similar oblique to vertical division takes place in the cell, *cd* (Fig. 3). The two cells, *m* and *ci* derived from the basal cell (Figs. 2, 3) may, however, divide earlier (Figs. 4, 5). An epiphysis initial appears to be cut off in the terminal cell following another oblique division (Fig. 6). In the following stages there is neither synchronisation nor regularity of divisions in the derivatives of the apical and basal cells with the result the embryo assumes various shapes. In some cases it has been observed that there is greater activity in the basal region of the embryo and the suspensor in such cases is massive and consists of several cells (Fig. 17). In other cases, however, the suspensor is elongated and presents only a few cells. An examination of a large number of preparations has enabled the following



TEXT-FIGS. 1–20. Stages in development of embryo, ×450.

TEXT-FIG. 21. Occurrence of two embryos in developing seed, ×225.

ca and *cb*, apical and basal cells of two-celled embryo; *m* and *ci*, daughter cells of *cb*;] *d* and *f*, daughter cells of *m*; *e*, epiphysis; *phy*, hypocotyledonary part; *h*, hypophyseal part; *s*, suspensor.

account to be given for the subsequent development of the embryo (Figs. 7 to 20).

The cell, *m*, may divide transversely giving the two superposed cells, *d* and *f* (Fig. 7). Several embryos were, however, found to show a vertical to oblique division in this cell (Figs. 4, 8). The subsequent shape assumed by the embryo appears to depend partly on the plane of first division of the cell, *m*. In the course of further development, the hypocotyledonary and hypophyseal parts of the embryo are differentiated. While it is not always possible to know the exact limits and also the origin of these two parts, it is evident, at least in some embryos, that the basal cell, *cb*, also contributes to the hypocotyledonary part (Figs. 15, 16). A part of the hypocotyledonary region is thus derived from the basal cell and the remaining portion from the apical cell. *Azadirachta* thus appears to belong to the third megarchetype in the first period in the system of embryogenic classification proposed by Souèges (1939). The hypophyseal part is derived from the inferior derivatives of the cell, *m*, (Figs. 19, 20) and this part eventually organizes the root cortex and the root cap. The suspensor which, as has already been mentioned, consists of varying number of cells is derived from the cell, *ci*. It may, however, be mentioned at this stage that the limit between the hypophyseal part and the suspensor is not always clear, particularly, in those cases where a massive basal region is present.

It is evident from the above description that *Azadirachta indica* definitely belongs to the first period in the system of embryogenic classification of Souèges by virtue of the fact that both the apical and basal cells of the two-celled embryo contribute to the embryo proper. The first tetrad of the C_2 category and an oblique division in the terminal cell *cc*, necessarily brings this in the fifth group and as the hypocotyledonary region is derived from both the apical and basal cells, *Azadirachta indica* can be considered as belonging to the third megarchetype.

Only one instance of polyembryony was met with. Two embryos were found in one of the preparations and as the embryos were in an advanced stage of development (Fig. 21) their exact origin could not be determined.

Summary

A detailed study of the development of the embryo in *Azadirachta indica* reveals that this species is ranged in the first period of the embryogenic system of classification. The embryo proper is derived from both the apical and basal cells of the two-celled embryo. There is considerable irregularity in the sequence and extent of cell divisions at the basal end which results in a suspensor of varying dimensions.

Acknowledgements

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and to Dr. M. A. Rau, for many helpful suggestions in the preparation of this paper.

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ON THE GENUS *AMPHICHÆTA* McALPINE

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(Received for publication on March 16, 1956)

The genus *Amphichæta* was described in 1904 by McAlpine. His diagnosis of the genus (McAlpine, 1904, p. 118) is as follows:—

> "Acervuli beneath the epidermis, often erumpent, disc- or cushion-shaped, black. Sporules elongated, with two or more transverse septa, at least partially coloured, and with one seta at each end; basidia hyaline, filiform."

Two species were described by him under this genus, *viz.*, *A. daviesiæ* on *Daviesia latifolia* R. Br. and *A. kennedyæ* on *Hardenbergia monophylla* Benth. and *Kennedya prostrata* R. Br. In establishing his new genus McAlpine compared his genus with *Cryptostictis* and stated that "in *Cryptostictis* Fckl. the spores are similar to those of *Amphichæta*, but they are enclosed in a perithecium" (McAlpine, 1904, p. 118). McAlpine's statement reflects the then current concept of *Cryptostictis*, as accepted by Saccardo (1884, p. 443), by Lindau (1900, p. 374) and by Allescher (1903, p. 251), who included this genus in the Sphæropsidales-Sphærioideæ. Later on, however, Hoehnel (1923, p. 342) classified *Cryptostictis* in the Melanconiales and this has been followed by Clements and Shear (1931) and by Ainsworth and Bisby (1954). Indeed, both Saccardo (1884) and Allescher (1903), whilst placing this genus in the Sphæropsidales, took care to mention in their generic descriptions of this genus that the fructifications are not typical (of the Sphæropsidales). When Hoehnel (1923) assigned *Cryptostictis* to the Melanconiales, he did away with the only difference between *Cryptostictis* and *Amphichæta* on which McAlpine erected his genus. One would, therefore, have normally expected *Amphichæta* being reduced to synonymy with *Cryptostictis* which was described much earlier. However, this was not done; on the other hand, Hoehnel accepted both the genera. In his key to the Melanconiales (Hoehnel, 1923, p. 342) *Cryptostictis* was distinguished from *Amphichæta* thus: *Cryptostictis* was stated to have conidia with only one basal appendage but no apical one, whereas *Amphichæta* was stated to have conidia with one basal as well as one apical appendage. Hoehnel's key relating to these two genera has been followed by Clements and Shear (1931) also.

Cryptostictis Fuckel was established in 1869 and the type species is *C. hysterioides* (Fuckel) Fuckel (≡ *Hendersonia hysterioides* Fuckel) (Saccardo, 1884). In erecting *Amphichæta*, McAlpine did not specify the type species of his genus; but since, of the two species he described, *A. daviesiæ* appeared immediately after the generic diagnosis followed by *A. kennedyæ*, the former may be considered the type species. We have been able to examine type material of both *Cryptostictis hysteri-*

oides (Fungi rhenani 1838, on *Vitis vinifera*, ca. Budenheim: Herbier Fuckel, 1894) and of *Amphichæta daviesiæ* (on stems of *Daviesia latifolia*, Ringwood, Victoria, 23–10–1903). Our study indicates that both these species are congeneric with each other since they are similar in the structure of the acervuli and the nature of the conidiophores and conidia. In both the species the conidia are phæophragmospores, and each conidium has one apical and one basal appendage, and the middle cells of the conidium are dark, the apical and the basal cells being hyaline. It is thus clear that Hoehnel was correct in classifying *Cryptostictis* in the Melanconiales; but he erred in considering the spores of *Cryptostictis* as having only one basal appendage, but no apical one. We, therefore, propose that *Amphichæta* McAlpine be relegated to synonymy with *Cryptostictis* Fuckel, in accordance with the rules of priority.

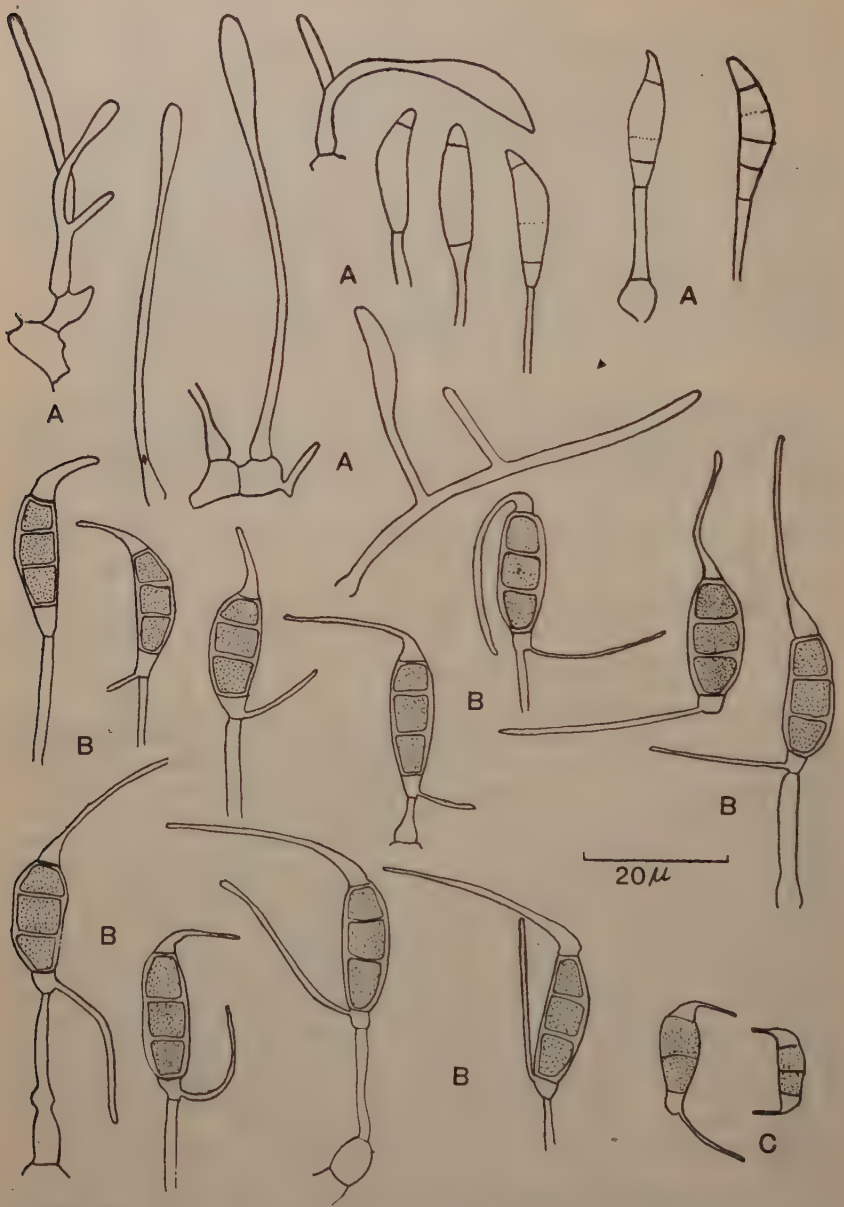
Accordingly, the two species of *Amphichæta* described by McAlpine (1904) are being transferred to *Cryptostictis*. The descriptions of the two species which are given below are based on a study of type specimens and they are largely in agreement with McAlpine's descriptions.

Cryptostictis daviesiae (McAlpine) Subramanian and Ramakrishnan comb. nov.

Basonym: *Amphichæta daviesiæ* McAlpine, 1904, in *Proc. Linn. Soc. N.S.W.*, **29**: 118; Saccardo, 1906, *Sylloge Fungorum*, **18**: 487.

The fungus forms black, scattered, separate or confluent, somewhat circular acervuli subepidermally on stems; they become erumpent later on. They are up to 1 mm. in diameter. A section through an acervulus shows a basal stromatic layer of 2–3 tiers of irregular, brownish, somewhat pseudoparenchymatous cells. Numerous conidiophores arise from the surface of the stroma. The conidiophores are hyaline, simple or branched, thin and long, non-septate, erect, straight or bent, up to 84 μ long and 1·6–2·4 μ wide. Each conidiophore or conidiophore branch bears at the tip one conidium. The mature conidium is somewhat fusiform, dorsiventral, 4-septate, 24–31 μ long and 8 μ broad. The three middle cells of the conidium are dark brown in colour and thick-walled; the apical and basal cells are hyaline. The apical cell is drawn out into a filiform, hyaline, simple, straight, curved or bent appendage 20–32 μ long. The basal cell is truncate at the locus of attachment to the conidiophore and is provided with one filiform, hyaline, simple, straight, curved or bent appendage 16–30 μ long and springing obliquely from near its junction with the conidiophore.

The type material of this species is exceptionally good and it has, therefore, been possible to study the development of the conidia in this species. The conidium arises as a short, hyaline, clavate swelling of the tip of the conidiophore. As this swelling enlarges it assumes the characteristic dorsiventral shape. The first septum to be formed appears to be the one immediately below the apex, followed by the



TEXT-FIG. 1. A and B. *Cryptostictis daviesiæ* from type specimen Herb. M.U.B.L. No. 156); A, Conidiophores and development of conidia; B, Mature conidia; C, *Cryptostictis hysterioides* conidia from type specimen Herb. M.U.B.L. No. 1514.

septum cutting off the basal cell of the conidium. Following or preceding this the conidium may be cut off by a septum from the conidiophore. The two middle septa of the conidium are then formed. Meanwhile, the central cells of the conidium gradually become darker and finally assume the characteristic colour of the mature spores. The apical cell then gradually gets drawn out into the characteristic caudate appendage. A little later, the basal cell also develops its appendage similarly.

Type specimen: on *Daviesia latifolia* R. Br. (Leguminosæ), Ringwood, Victoria, Australia 23–10–1903, coll. C. French Jr., Herb. M.U.B.L. No. 1569 ex Herb. Department of Agriculture, Burnley Gardens, Victoria, Australia.

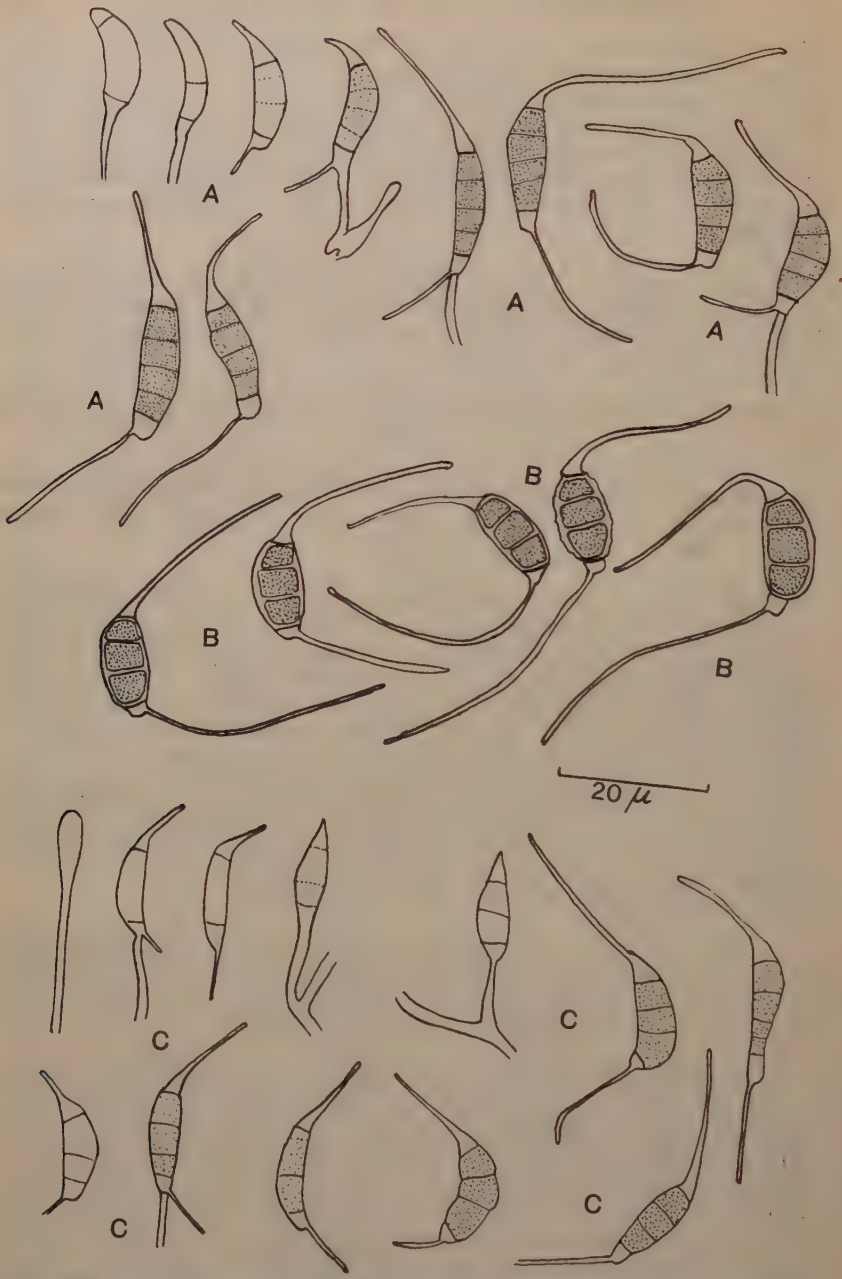
Cryptostictis kennedyae (McAlpine) Subramanian and Ramakrishnan comb. nov.

Basonym: *Amphichæta kennedyæ* McAlpine, 1904, in *Proc. Linn. Soc. N.S.W.*, **29**: 119; Saccardo, 1906, *Sylloge Fungorum*, **18**: 486.

The fungus forms small, black, erumpent, scattered acervuli on the leaves. The conidiophores are filiform, hyaline, much shorter than those of *C. daviesiæ*, and 10–16 μ long. Each conidiophore bears one conidium acrogenously. The conidium is fusiform, slightly dorsiventral, 5-septate, 24–28·2 × 6·4–8 μ, and with the middle four cells brown in colour. The apical and the basal cells are hyaline. The apical cell is drawn out into a caudate, filiform, simple, slightly curved, hyaline appendage 31–40 μ (6–17 μ according to McAlpine) long. The basal cell is truncate at the locus of attachment to the conidiophore and has one filiform, simple, hyaline, straight or curved appendage 24–35 μ (9–22 μ according to McAlpine) long and springing obliquely from near the junction with the conidiophore.

Type specimen: In dry portions of leaves of *Kennedya prostrata* R. Br. (Leguminosæ), Cheltenham, Victoria, Australia, 27–9–1903, coll. C. French Jr., Herb. M.U.B.L. No. 1571 ex Herb. Department of Agriculture, Burnley Gardens, Victoria, Australia.

Another collection was also assigned to this species by McAlpine (1904, p. 119), *viz.*, on leaves of *Hardenbergia monophylla* (recorded as *Kennedya monophylla* in herbarium specimen), Ringwood, Victoria. The material available of this species is very meagre. We have, nevertheless, examined this specimen. We find that it is not conspecific with *Cryptostictis kennedyæ* since the conidia are 4-septate and are shorter and thicker than those of *C. kennedyæ*. Only conidia could be seen from the meagre material available and the conidia are fusoid, dorsiventral, 4-septate, 19–27 μ long and 8–9·6 μ broad. The middle cells are dark brown in colour and thick-walled; the apical and the basal cells are hyaline. The apical cell is drawn out into a caudate, filiform, simple, curved or bent appendage 19–34 μ long. The basal



TEXT-FIG. 2. A, *Cryptostictis kennedyæ* from type specimen Herb. M.U.B.L. No. 1571; development of conidia and mature conidia; B, *Cryptostictis macalpineæ* from type specimen Herb. M.U.B.L. No. 1570: mature conidia; C, *Cryptostictis grevilleæ* from type specimen Herb. M.U.B.L. No. 1535, development of conidia and mature conidia.

cell is truncate at the locus of attachment to the conidiophore and has an appendage arising obliquely from near the junction with the conidiophore. It is filiform, simple, hyaline and 24–46·4 μ long.

This fungus is sufficiently different from *Cryptostictis daviesiæ* and *C. kennedyæ* to be considered a separate species. Its conidia are shorter and stouter and have longer basal appendages than those of *C. daviesiæ* and *C. kennedyæ*. We, therefore, propose a new species for it, named after D. McAlpine.

Cryptostictis macalpineae Subramanian and Ramakrishnan sp. nov.

Acervulis minutis, nigris, erumpentibus, sparsis. Conidiis fusiformibus, leniter curvulis, 4-septatis, cellulis medianis coloratis, extimis hyalinis, 19–27 × 8-9·6 μ; setula apicali 19–34 μ longa, basilari obliqua, 24–46·4 μ longa. Hab. in areis siccis foliorum *Hardenbergiæ monophyllæ* (Leguminosæ), Ringwood, Vict., Australiæ, 12–9–1903, leg. C. French Jr., Herb. M.U.B.L. No. 1570 ex Herb. Department of Agriculture, Burnley Gardens, Victoria.

Since McAlpine described his genus, several species of *Amphichæta* have been described. Of these, we have been able to obtain part of the type material of *Amphichæta grevilleæ* Loos which was described by Loos (1950) as causing a disease of *Grevillea robusta* seedlings in Ceylon. This is a good *Amphichæta* and it is, therefore, congeneric with the type species of *Cryptostictis*. Accordingly, we propose the following new combination:—

Cryptostictis grevilleae (Loos) Subramanian and Ramakrishnan comb. nov.

Basonym: *Amphichæta grevilleæ* Loos., 1950, in *Trans. Brit. mycol. Soc.*, **33**: 41–42.

The fungus forms acervuli on diseased leaves. The acervuli are black, scattered, erumpent and amphigenous. The conidiophores are filiform, hyaline, simple or branched, and 12–15 × 1·3 μ. Each conidiophore or branch bears one conidium accrogenously. The mature conidia are fusiform, dorsiventral, predominantly 4-septate, and 17·6–24 × 4·8–8 μ. The central cells of the conidia are pale brown in colour; the apical and the basal cells are hyaline. The apical cell is drawn out into a filiform, hyaline, simple, usually straight appendage 16–18 μ long. The basal cell is truncate at the locus of attachment to the conidiophore and is provided with one filiform, hyaline, simple, usually straight appendage 11–18 μ long and springing obliquely from near the junction with the conidiophore.

Type specimen: on leaves of *Grevillea robusta* A. Cunn., Kandapolla, Ceylon, Herb. M.U.B.L. No. 1535 ex Herb. Tea Research Institute of Ceylon No. 437.

Summary

A study of the type material of the type species of *Cryptostictis* Fuckel [*C. hysterioides* (Fuckel) Fuckel, 1869] and of *Amphichæta* McAlpine (*A. daviesiæ* McAlpine, 1904) has shown that both the species are congeneric. *Amphichæta* McAlpine is, therefore, reduced to synonymy with *Cryptostictis* Fuckel. *Amphichæta daviesiæ* McAlpine, *A. kennedyæ* McAlpine and *A. grevilleæ* Loos are transferred to *Cryptostictis*, following a study of type material of these three species. One collection on *Hardenbergia monophylla* from Australia assigned by McAlpine to *Amphichæta kennedyæ* was found to be distinct from that and other species, and a new species, *Cryptostictis macalpineæ* is proposed to take it.

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STUDIES ON THE CYTOLOGY AND PHYLOGENY OF THE PTERIDOPHYTES

I. Observations on the Marattiaceæ

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Introduction

An investigation on the cytology of the South Indian Pteridophytes was started in 1952, in the Botany Department of the Travancore University. The considerations which prompted this venture are threefold: (1) the south-west region of peninsular India is very rich in Pteridophytes and this group has not received sufficient attention from Botanists; (2) it was found easy to grow in the Botanical Garden of the University several Pteridophytes which were believed to thrive only in much higher altitudes, thus facilitating easy availability of material for study; and (3) the realisation that cytological studies in the living representatives of this ancient group of plants might throw valuable light on taxonomy and phylogeny.

During the course of the last three years over a hundred species of Pteridophytes have been studied cytologically and it is proposed to publish the results in convenient instalments dealing with major groups. This paper deals with the cytology of the South Indian Marattiaceæ.

Represented by seven genera of living ferns and with a fossil record dating back to the Palæozoic period, the Marattiaceæ is a well-defined family of relatively primitive ferns. All the seven genera are tropical in distribution. *Angiopteris* and *Marattia* are the only two genera that are indigenous to South India. *Angiopteris evecta* (Forst.) Hoffm. was collected from several localities in the Western Ghats, like Ponmudi (1,500–3,000 feet elevation), Munnar area (3,000 feet), Thekkady (2,500 feet), Parambikulam (2,000 feet), etc. *Marattia* is represented by only one species, *M. fraxinea* Smith. and was obtained from Kodaikanal hills (at an elevation of 7,000 feet). Both genera are confined to higher elevations, in humid, shady areas, and when brought to the plains thrive well under green house conditions.

Methods

The cytological difficulties inherent in most members of the tropical ferns, like the small size and thick wall of the spore mother cells (Manton, 1954) together with the diffuseness of outline of the meiotic chromosomes, though shared by both the genera are most marked in *Angiopteris*, which makes it a difficult cytological material. *Marattia* on the other hand is relatively easy to handle. The fixative used was Carnoy's fluid with a modified proportion of absolute alcohol,

glacial acetic acid and chloroform (Ninan, 1955). Sporangia were fixed for not less than 24 hours and acetocarmine smear technique was used throughout. Root tips were fixed in Carnoy's fluid for at least 24 hours after keeping the fresh roots in a refrigerator at close to 0° C. for 24 hours. Photographs were taken from permanent preparations. Explanatory diagrams were drawn on enlarged photographic prints and reduced to the desired size in reproduction.

Cytological Observations

Angiopteris.—Meiosis in spore mother cells was studied in *Angiopteris evecta* from two localities, both from Ponmudi area in Western Ghats. Appreciable difference was observed in the size and position of sporangia in the two materials. In both cases, there were clearly 80 bivalents at the first meiotic division (Text-Fig. 1 and Plate IX, Fig. 1). Root-tip counts clearly showed the presence of 160 chromosomes (Text-Fig. 3 and Plate X, Fig. 3). The chromosomes (both meiotic and mitotic) show a slightly fuzzy outline and this feature was observed in certain other genera of the Eusporangiate ferns also. Manton (1954) has recorded $n = 40$ in *A. hypoleuca* de Vriese. from a plant growing at Kew and $n = 80$ in *A. evecta* (Forst.) Hoffm. from two Ceylon specimens, clearly showing the existence of polyploidy in this genus. The present observation shows that in chromosome number Travancore material is similar to those studied by Manton from Ceylon. In a recent paper Mehra and Singh (1955) have reported $n = 40$ in *Angiopteris evecta* from Darjeeling, Himalayas.

Marattia.—Only one plant of *M. fraxinea* collected from Kodaikanal was studied. This gave very clear preparations showing 78 bivalents at meiosis (Fig. 2 and Pl. IX, Fig. 2). In all preparations made during two seasons, and also in materials fixed originally in the wild condition, it was found that one of the bivalents was distinctly smaller than the other 77 which were nearly of the same size. Except for this small bivalent, the size of the chromosome is comparable to the chromosomes of *Angiopteris*. To confirm the number definitely, root-tip smears were examined. Several clear preparations were obtained showing 156 chromosomes at metaphase, of which 2 were markedly smaller than the rest (Text-Fig. 4 and Pl. X, Fig. 4). This removes any doubt as to the nature of the small chromosome seen at meiosis—it is clearly a bivalent.

Phylogenetic Considerations

The family Marattiaceæ is of great interest in so far as it shows in living genera features which recall in a striking manner those found in extinct forms. Features of the sorus in certain fossils assigned to this

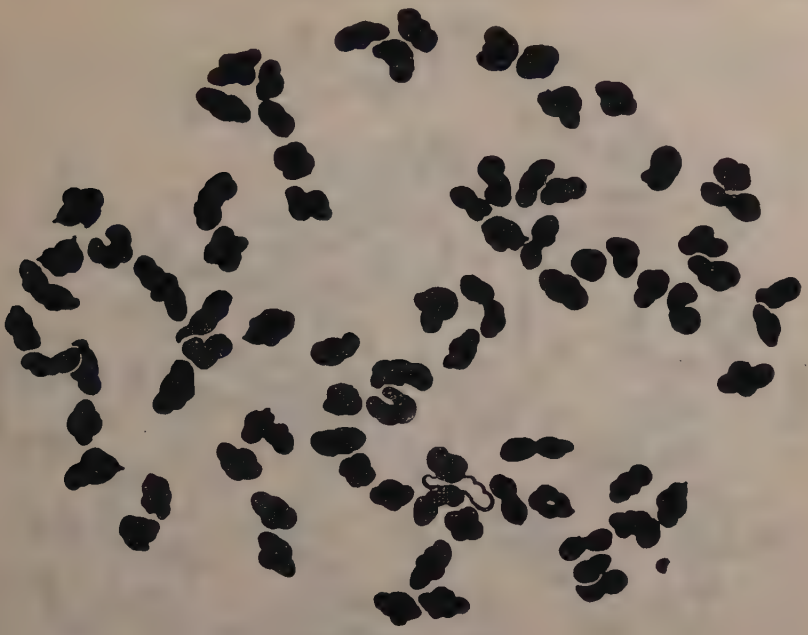


FIG. 1

FIG. 2

TEXT-FIGS. 1–2. Fig. 1. Explanatory diagram showing meiosis in *Angiopteris evecta*. 80 bivalents are clearly seen, ×2,000. Fig. 2. Explanatory diagram of meiosis in *Marattia fraxinea*. The number of bivalents is 78, of which the one indicated by the arrow is appreciably smaller than the rest, ×2,000.

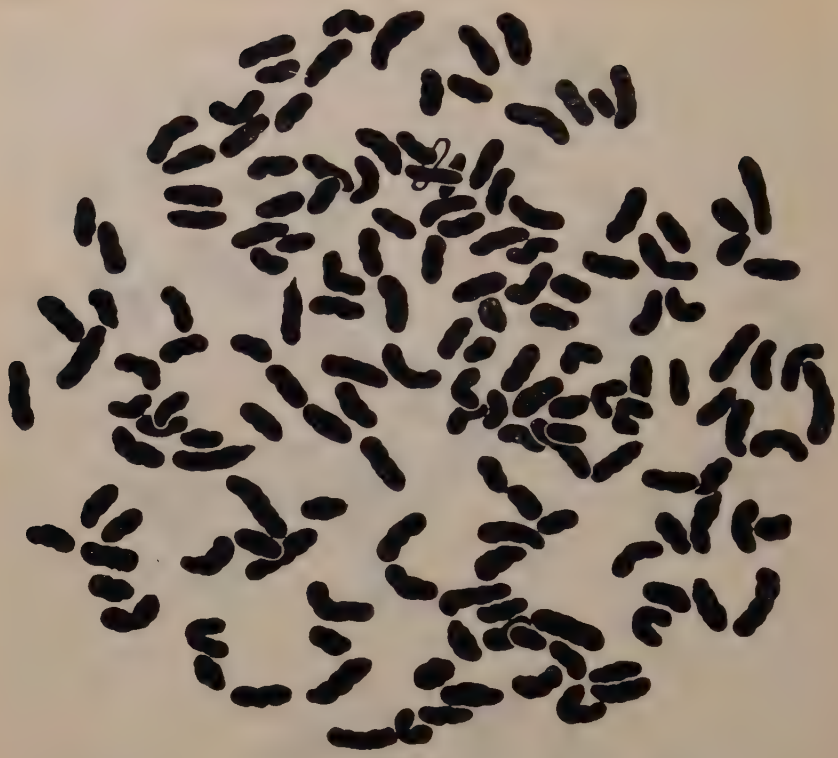


FIG. 3

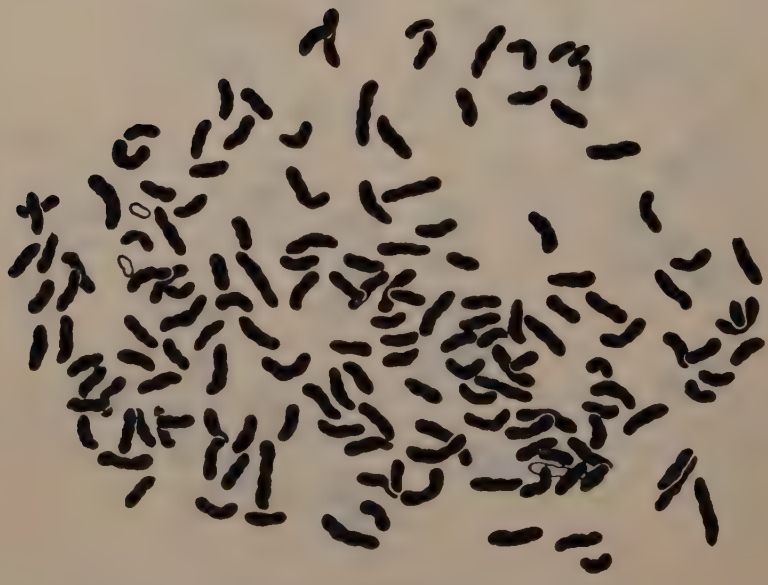


FIG. 4

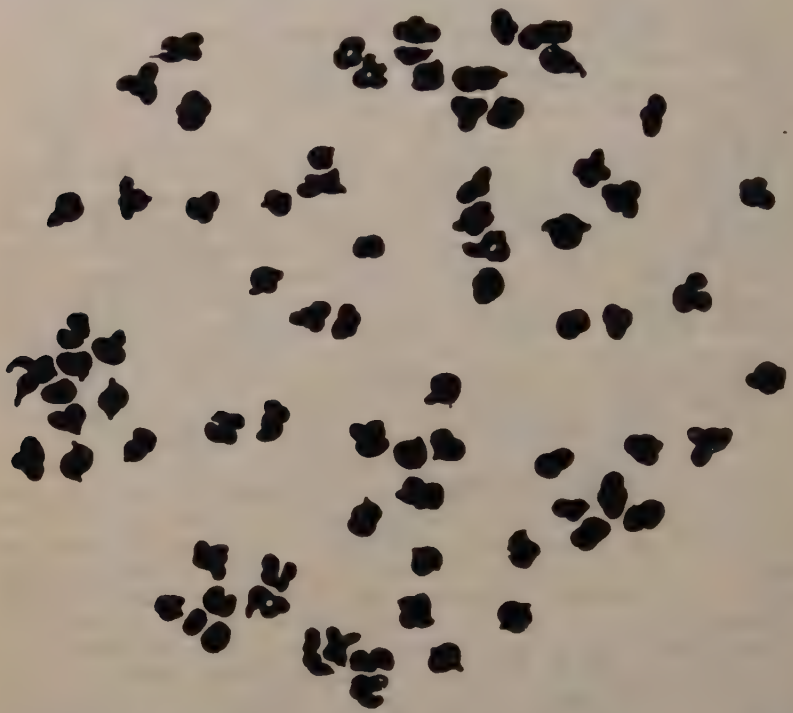
TEXT-FIGS. 3–4. Fig. 3. Explanatory diagram of mitosis in *Angiopteris evecta*. The somatic chromosome number is 160, ×1,800. Fig. 4. Explanatory diagram of mitosis in *Marattia fraxinea*. Out of the 156 chromosomes, two are markedly smaller, ×1,800.

family are exactly similar to those in some of the living genera. As Bower (1926) has remarked "nothing in Palæobotany is more striking than a detailed comparison of the Palæozoic sori of *Ptychocarpus* or of *Scolecopteris* with those of the living *Christensenia* and *Marattia*". The living genera show many archaic features and have not much in common with the other families of ferns; "they appear as survivals to the present day of a Palæozoic and Mesozoic Stock."

Bower (1926) from a careful comparative study of the different genera of the Marattiaceæ has subdivided the family into three phyletic groups: (1) Sporangia separate (*Angiopteris*, *Macroglossum*, *Archangiopteris* and the fossil form *Danæopsis*); (2) Sporangia united into Synangia (*Ptychocarpus* a fossil, *Marattia*, *Protomarattia* and *Danæa*); and (3) Sori subdivided (*Christensenia*). Of the seven living genera materials of only two were available for the present study. The presence of chromosome numbers $n = 40$ and $n = 80$ in *Angiopteris* sps. (Manton, 1954 and the present observations) clearly shows that in this family also polyploidy has played a role in evolution of species. Though there is no evidence of the existence of a number lower than 40, observations on a large number of genera of Pteridophytes led Manton (1953) to suggest that this number may have arisen from a number as low as 10. The presence in *Marattia* of a chromosome number different from *Angiopteris* is of great interest especially in view of the fact that this number ($n = 78$) is an exact multiple of 13, which is found in other primitive Pteridophytes. Manton (1950, 1954) has recorded $n = 13$ in *Hymenophyllum*, $n = 26$ in *Matonia* and $n = 39$ in *Dicranopteris*. (*Gleichenia* sens. lat.). Observations on materials of *Dicranopteris* collected in Travancore also show the chromosome number to be a multiple of 13 ($n = 78$) (Text-Fig. 5). The presence in *Psilotum nudum* L. of a polyploid series with numbers in multiples of 26 (Ninan, 1956) together with the above observations clearly suggest that the chromosome number 13 must have been widely prevalent in the past in primitive groups.

It seems reasonable to assume that the Marattiaceæ must have originated from ancestors with 13 as the basic chromosome number, and the situation in *Angiopteris* is a condition derived from this. On morphological considerations the two genera *Angiopteris* and *Marattia* fall into two distinct groups, the latter clearly being a direct survival of the ancient types. While the chief difference between the two genera is in sporangial character, it may be noted that there is considerable similarity between the two genera in external features, and the one is easily mistaken for the other if sporangia are absent. Therefore we need not suppose that the two genera have originated from different ancestral types. The greater probability appears to be that both had a common origin in some ancestral type with 13 as the basic chromosome

number, and in *Angiopteris* duplication of one chromosome has given rise to $n = 40$, and from this the forms with $n = 80$ might have arisen, while in *Marattia* the number is retained as an exact multiple of 13. It would be very desirable to find the cytological situation in the other five genera of this family. The difficulty in procuring material has so far prevented this being done.



TEXT-FIG. 5. Diagram showing meiosis in *Dicranopteris linearis*. 78 bivalents are clearly seen, ×2,000.

Regarding the relationship of the Marattiaceæ with other families of ferns, Bower (1926) has suggested analogy in the structure of the sorus to the Gleicheniaceæ and Matoniaceæ. The suggestion of this relationship is amply supported by cytological evidence in that *Matonia*, *Gleichenia* and *Marattia* are traceable back to a base number as low as 13.

SUMMARY

The cytology of *Angiopteris evecta* and *Marattia fraxinea* from South India is described. The chromosome number in *Marattia* ($n = 78$) is different from that in *Angiopteris* ($n = 80$). Certain phylogenetic aspects are discussed in relation to chromosome numbers in the Marattiaceæ, Gleicheniaceæ and Matoniaceæ. Evidence is pre-

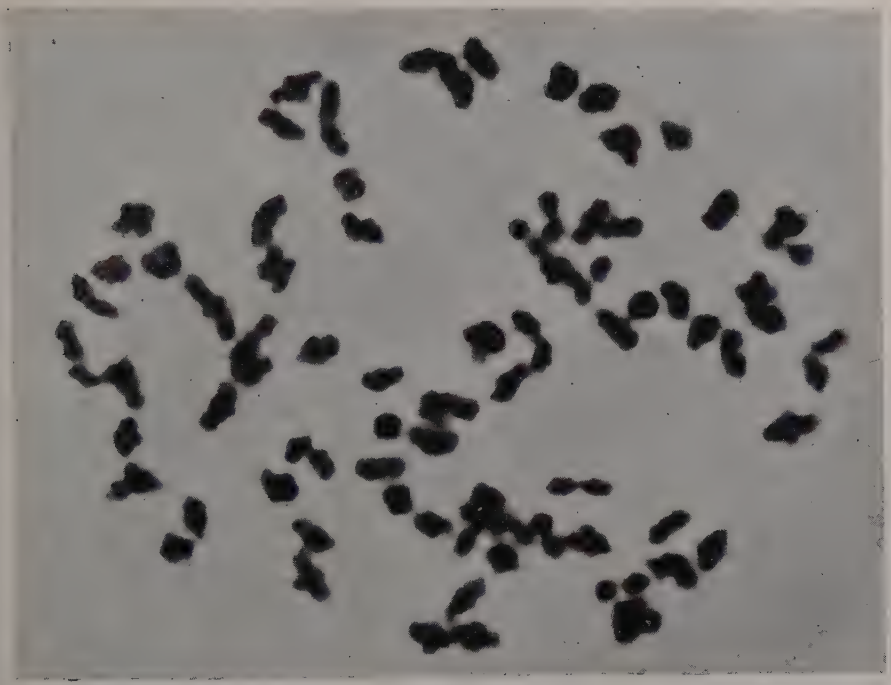


FIG. 1

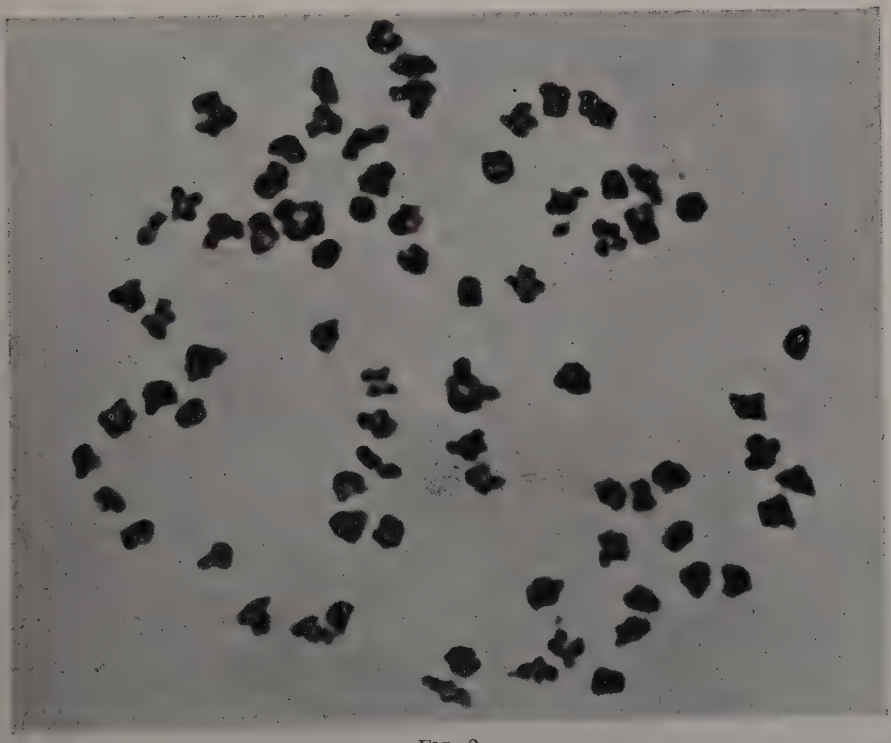


FIG. 2

C. A. Ninan

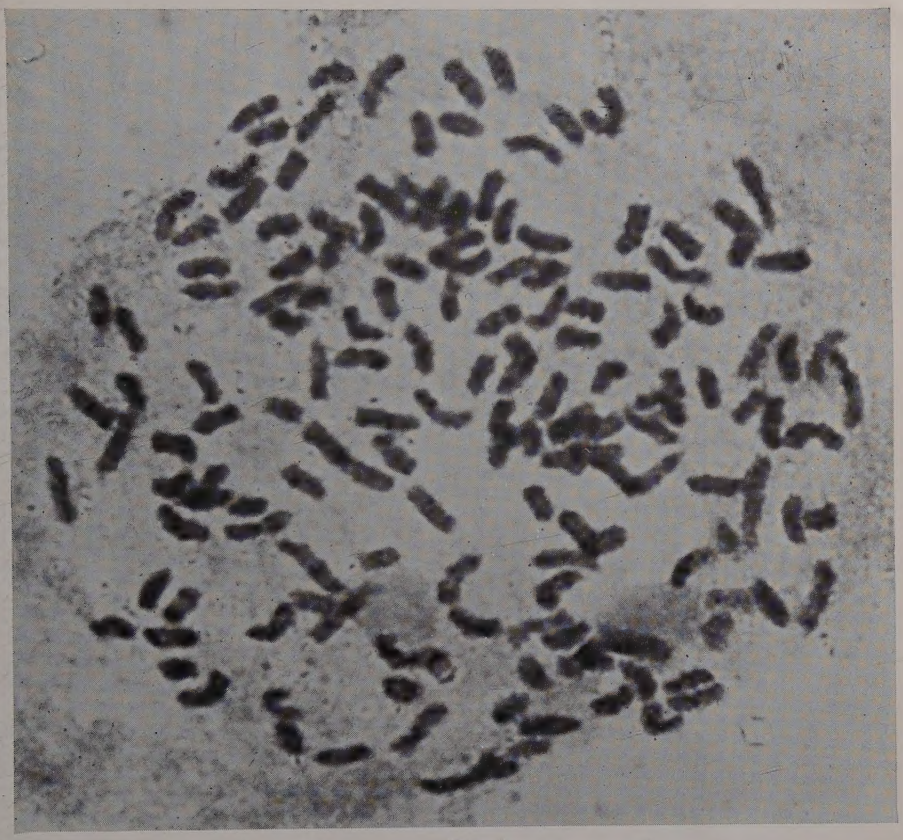


FIG. 3

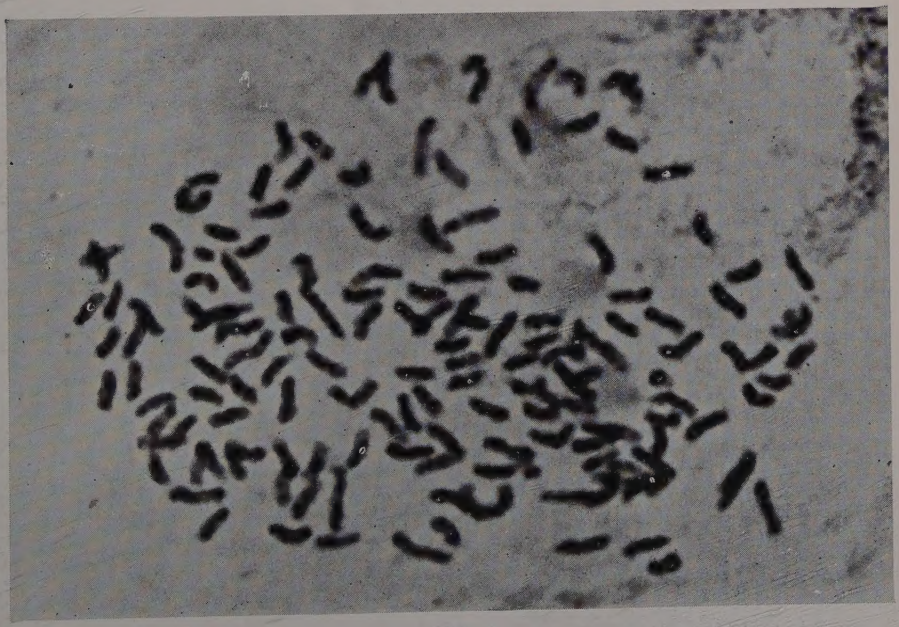


FIG. 4

sented to show that 13 is probably a common basic chromosome number in the ancient vascular Pteridophytes. *Marattia fraxinea* shows an exact multiple of this number, while *Angiopteris evecta* has a slightly higher number derived from this.

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Explanation of Plates

Plate IX

Figs. 1–2. Fig. 1. Microphotograph of chromosomes of *Angiopteris evecta* showing meiosis in a spore mother cell. The chromosome number is clearly $n = 80$. Note the fuzzy outline of the chromosomes, ×2,000. Fig. 2. Meiosis in a spore mother cell of *Marattia fraxinea* showing 78 bivalents, of which one is extremely small, ×2,000.

Plate X

Figs. 3–4. Fig. 3. Root-tip squash of *Angiopteris evecta* showing 160 chromosomes. Note the peculiar texture of the chromosomes, ×1,800. Fig. 4. Somatic mitosis from a root-tip squash preparation of *Marattia fraxinea*. 156 chromosomes are clearly seen, ×1,800.

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